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AN APPROACH TO METAL FATIGUE

by F. B. Stulen, J. H. Redfern, and W. C. Schulte

Prepared under Contract No. NAS 1-3170 *by*
CURTISS-WRIGHT CORPORATION
Caldwell, N. J.
for

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TABLE OF CONTENTS

	PAGE
SUMMARY	1
INTRODUCTION	1
SYMBOLS	4
THE TEST PROGRAM	6
MATERIALS USED FOR INVESTIGATION	8
APPARATUS USED FOR THIS INVESTIGATION	9
Fatigue Machines and Grip Design	9
Equipment for Recording Crack Propagation	11
TEST PROCEDURE AND PRESENTATION OF DATA	12
Crack Generation	12
Phase I Testing	13
Phase II Testing	14
Phase III Testing	15
ANALYSIS OF TEST RESULTS AND DISCUSSION	17
The Critical Dynamic Crack Length and Stress	17
Crack Propagation	19
Analysis of Delay-Cycles	25
A Suggested Cumulative Fatigue Damage Relation	27
CONCLUSIONS	30
REFERENCES	32
FIGURES AND GRAPHS	35
TABLES	54

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SUMMARY

This investigation was undertaken to establish qualitatively and quantitatively some of those factors that are of primary importance in the fatigue of metals. For this investigation, the material used was titanium 8 Al - 1 Mo - 1 V alloy sheet in the Triplex-Annealed condition. This research program was limited to investigating three phases: (1) the fatigue limit associated with a crack; (2) the rate of crack propagation; and (3) the stress interaction effect, or the delay-cycle effect. pq 8

Each of these effects is described by one or more proposed formulas, and the parameters associated with each were obtained by standard statistical methods. The rms-error between the test data and the corresponding computed values was employed as a measure of the goodness-of-fit of the proposed formulas. Reasonably good fits were obtained between the test data and some of the proposed relations.

A cumulative fatigue damage relation has been developed based on these findings.

INTRODUCTION

In the analysis of fatigue damage of structures and machines, many empirical rules have been suggested. Some of these suggested treatments of the fatigue damage problem do not take into account the factors of crack initiation, crack propagation, the influence of notches and other types of discontinuities, stress interaction and the changing fatigue limit as the crack progresses. In the present investigation, an attempt has been made to develop an approach to the metal fatigue problem in which some of these factors that bear on the total problem are considered.

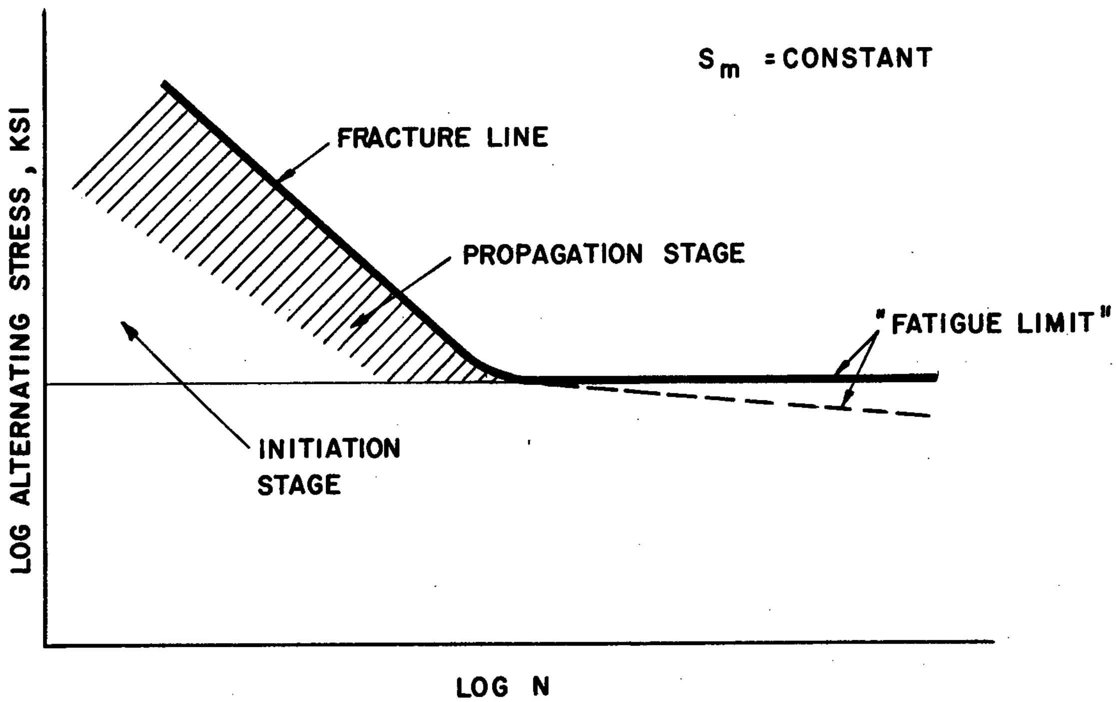
Although in the analysis of cumulative fatigue damage of structures and machines, the empirical linear rule (Palmgren-Miner hypothesis) is often conservative, several investigators (1), (2), in recent years have found that this simple rule may be very unconservative under certain loading conditions. For example, Schijve (3) states "The Palmgren-Miner rule is unreliable for judging whether a certain type of service load will contribute substantially to damage induced by other types of loadings". In some recent investigations the fatigue life has been overestimated by a factor of 5 or more by the linear rule. Although the linear rule is a very simple method for the estimation of fatigue life of a structural element or machine component, and is currently used by many designers for preliminary estimates of fatigue life, there are no precise rules for computing the convervatism or unconservatism of the linear rule. (There are, however, several qualitative explanations for these errors).

Numerous other theories and corresponding formulas have been proposed for more precise assessment of cumulative fatigue damage. Grover (4) in a review of these stated that most relations have one or more of the following limitations: (1) no physical mechanism is clearly defined, (2) too many experimental data are required, and (3) mathematical calculations are cumbersome.

Considerable effort (5) has been sponsored in recent years to "explain" the mechanism of fatigue at the microscopic or sub-microscopic level but this general approach has not, as yet, offered any practical solution that can be applied directly to engineering problems. Apparently the mechanisms that may be dominant in the initiation and propagation of a crack are considerably complex.

In order to establish engineering formulas that are more precise than the linear rule, qualitative and quantitative evaluations of (1) crack initiation, (2) crack propagation, (3) fatigue limit, and (4) delay cycles appear to be necessary. "Delay cycles" may be defined as the number of cycles required to re-initiate the growth of a crack after a change in stress level has taken place. This report describes several possible relations for quantizing these effects and experiments performed to evaluate the precision of these.

The basis for this approach to a general analysis of fatigue processes and for the estimating of cumulative fatigue damage is illustrated in the sketch on the following page.



THE IDEALIZED S-N CURVE

This S-N curve is an idealized representation of smooth or notched laboratory specimens, or simple structural or machine elements. Since, in many types of structural or machine elements, the notch or stress-raiser is highly localized (such as rivet holes, oil holes, material defects, etc.), only this type of notch will be considered. For similicity, the lower branch of the S-N curve will be considered as being parallel to the abscissa, although many non-ferrous materials exhibit a slight slope for this branch. (There are possibly several explanations for this slope such as atmospheric corrosion, metallurgical instability, etc.). As such, this lower branch corresponding to the "fatigue limit" may be considered to be a "threshold value" for crack propagation.*

* In notched specimens and sometimes in smooth specimens, non-propagating cracks have been observed at, or somewhat below, the fatigue limit.

The region between the ordinate and the upper branch of the S-N curve is usually considered to be divided into two regions: (1) crack initiation and (2) crack propagation. Since the detection of the origin of cracks in a fatigue process depends on the precision of the inspection technique, the division of the fatigue process into these two stages requires special consideration. One method by which these two stages can be defined is by the concept embodied in the French Damage Line Theory. An adaptation of this concept will be used later on in discussing cumulative damage.

This present investigation proposes an approach to the analysis of fatigue that requires measurements of the following relations:

(1) The "critical dynamic crack length and stress" as a function of the crack length and the stress conditions used to form the crack. (This is the same as the fatigue limit associated with a crack of a specific length).

(2) The rate of crack growth as a function of the stress of the test and the crack length.

(3) The stress-interaction effect. The stress interaction effect is defined in this report to be the influence of the prior stress condition on the rate of crack propagation at the stress condition being considered. This effect is evaluated by the delay cycles, defined on page 2.

Expressions for these relationships are presented in a later section as well as a discussion of the test results.

SYMBOLS

Legend

$K\ (s_a, s_m)$ = function of gross mean and alternating stresses that defines the quantity $d(\log \ell)/dN$ at that stress condition - $(\text{cycles})^{-1}$.

K_N = stress concentration factor based on the Neuber parameter (16).

Symbols - Continued

Legend

ℓ	=	crack length (tip to tip) - in.
ℓ_o	=	initial crack length - in.
ℓ_d	=	critical dynamic crack length (associated with the fatigue limit at 5×10^6 cycles of a specimen with a crack length of ℓ_d) in.
ℓ_r	=	critical length of crack for <u>static</u> failure at reference (highest) stress in the spectrum - in.
s_a	=	gross alternating stress - ksi
s_{a_i}	=	gross alternating stress value in the spectrum at the i^{th} load - ksi
s_e	=	equivalent gross stress - ksi
s_f	=	fatigue limit (5×10^6) in terms of (gross) alternating stress - ksi
s_m	=	gross mean, or steady, stress - ksi
s_{m_i}	=	gross mean, or steady, stress in the spectrum at the i^{th} load - ksi
s_{net}	=	maximum net stress in the cycle - ksi
s'	=	a constant related to the residual stress developed in the formation of the crack - ksi
s_{a_r}	=	gross reference alternating stress level - ksi
N	=	number of cycles
n_i	=	number of cycles in the propagation stage at the i^{th} stress condition
N_o	=	number of cycles corresponding to the development of a crack of length ℓ_o

Symbols - Continued

Legend

N_r	=	number of cycles to failure at the reference stress level
D	=	fatigue damage (defined by formulas 17 and 18)
R	=	ratio of minimum (gross) stress in the cycle to the maximum (gross) stress in the cycle
Φ	=	stress-interaction function
b, β, α k, C,	=	parameters in the various formulas (usually related to the material)
ρ', A, B, C γ	=	constants in the formula of reference 16

Subscripts

a	=	alternating (stress)
d	=	delay cycles
f	=	fatigue limit (stress)
i	=	indicial notation, the i^{th} condition
m	=	mean (stress)
N	=	subscript on the stress concentration factor to designate the Neuber modification of the geometric stress concentration factor
net	=	net (stress)
r	=	reference (stress)

THE TEST PROGRAM

The work performed to evaluate this approach and the development of testing techniques required to obtain these constants for any material, was divided into the following three phases. The Ti - 8 Al - 1 Mo - 1 V alloy was used as a test material.

Phase I

Purpose. - To develop techniques for the evaluation of the "critical dynamic crack length and stress" (fatigue limit associated with a crack), and to determine the influencing variables.

Program. - Cracks of a given predetermined length were produced in specimens at a specific prestress value and these specimens were tested to determine the fatigue strength at 5×10^6 cycles. A semi-empirical formula is later proposed and tested statistically using these experimental data.

To accomplish this phase of the program specimens were produced with a small hole (.005 - .007 inch diameter) in the center of the test section. Specimens were loaded to a stress such that cracks developed in a small number of cycles. These cracks were grown to predetermined lengths (0.020", 0.042" and 0.095").

It was initially intended that specimens were to be subjected first to a stress that would not cause growth of the crack, or failure after the initial 5×10^6 cycles of stress. The stress level would then be raised by a given increment and stress cycling repeated for another 5×10^6 cycles, or until failure. This process was to have been repeated until a stress level was reached where failure did occur within the 5×10^6 cycles. The program was started in this manner but it was found that the stress cycles imposed on the specimens below the stress level where failure occurred changed the fatigue strength of the material to such an extent that the final fatigue strength was raised significantly. These findings will be discussed in detail in a later section of this report.

As a result of these findings the test program was modified and each specimen was tested at only one stress level. From the results of the several specimens of each crack length tested in this manner, an S-N curve was constructed and estimates made of the fatigue strength at 5×10^6 cycles associated with each crack length.

Phase II

Purpose. - To investigate some of the various factors that influence the rate of crack propagation.

Program. - Cracks of two different lengths were generated in the specimens. These specimens were then each tested at a given mean and alternating stress such that propagation of the crack would occur. By means of sequence photography, the crack growth was monitored so that the rate of crack propagation could be determined. The variables studied were, (a) initial crack

length, (b) mean stress, and (c) alternating stress. Insofar as it was possible, a portion of the data obtained from specimens tested in Phase II was also used in the Phase I portion of the program.

Phase III

Purpose. - To investigate the various factors that influence the stress interaction effect on crack propagation and how the delay-cycles may be taken into account when a spectrum of imposed stresses is involved.

Program. - Cracks of two lengths were generated. From Phase II, part of an S-N curve for each crack length at each mean stress was obtained. Specimens of one crack length were tested at one mean stress and at an initial alternating stress, until crack length growth was clearly evident. The testing was stopped and the alternating stress changed to a different level. The specimen was then subjected to fatigue stress for a predetermined percentage of the life expected at the new alternating stress level or until failure occurred. If failure did not occur, the testing was continued at a higher stress level.

MATERIAL USED FOR INVESTIGATION

The material used for this investigation was Ti - 8 Al - 1 Mo - 1 V alloy sheet. This material was supplied to the Curtiss-Wright Corporation, Curtiss Division by NASA from the lot of material being investigated for the commercial supersonic transport (SST) program. The chemical analysis report supplied by the manufacturer shows the following analysis:

C	0.023 %
Fe	0.09
N_2	0.013
Al	7.6
V	1.0
Mo	1.1
H_2	0.003 - 0.007
Ti	Remainder

The tensile property tests reported were as follows:

	Yield Strength psi 0.2% Offset	Ultimate Tensile Strength psi	Elongation %
Typical	136,000	152,500	12.5
Lows	130,000	140,500	11.0
Highs	140,000	157,800	14.5

Pg 30

The sheet supplied was nominally 96" x 36" x 0.050" thick. Actual thickness of the sheet varied from 0.040" to 0.044". The material was in the Triplex Annealed condition and reported to have been given the following thermal treatment after final rolling:

(a) 1450°F for 8 hours, furnace cooled

(b) 1850°F for 5 minutes, air cooled

(c) 1375°F for 15 minutes, air cooled

No further thermal treatments were given the material prior to test.

The fatigue specimens were prepared in accordance with specimen drawing Figure 1. All fatigue specimens were cut with the longitudinal axis of the specimen parallel to the long axis of the sheet. Each specimen blank was identified so that its original location within the sheet could be ascertained. The locations of the specimens are shown in Figure 2.

A small hole, approximately .005-.007 in diameter was drilled, or electro-discharge machined, in the center of the test section of the specimen. The edge of this hole was then electro-etched to remove the work-hardened material around the hole and produce a residual stress field favorable to crack initiation.

APPARATUS USED FOR THIS INVESTIGATION

Fatigue Machines and Grip Design

The testing performed in this investigation was done on two axial fatigue machines of the constant load type with a capacity of 5000 pounds steady load (either compression or tension) plus an alternating load of ±5000 pounds. These machines operate at 1800 cycles per minute.

Sheet specimen grips were designed and built to permit the use of the threaded fixture of the fatigue machine. The specimens were held to the grips by means of a clamp. Five 1/4-20 cap screws held the clamp and the specimen to the grip. The cap screws were locked in place with nuts. Serrations were cut in the grip and the clamp plate to prevent axial movement of the specimen. In order to obtain precise alignment of the specimen in the grip, the specimen had two reamed 1/8" holes on the centerline 4-3/4" apart. The grips and clamp plates also had a reamed hole on the centerline. A dowel pin was used to align the specimen in the grip before the cap screws locked the specimen in place.

The fatigue testing machine was aligned by fixing a specimen in its grips and fixture to the oscillator plate of the machine. The upper end of the fixture was then allowed to align itself and was locked in place by means of wedges and spherically seated screws so arranged that no movement of the upper end of the fixture took place during the locking operation. This system was adequate for a stiff specimen, but a sheet specimen would not be stiff enough to permit alignment by this method. Therefore, a dummy specimen was made of a steel channel. This dummy specimen had the same reamed holes as the specimen. The dummy specimen was pinned to a grip at each end and then the grips placed in a tensile machine under light load and the dummy specimen was screwed to the grips. This assured vertical alignment of the grips and dummy specimen. This assembly was then placed in the fixtures of the fatigue testing machine, and the fixtures aligned. Figure 3 shows the dummy specimen and grips assembled in the fatigue testing machine. The dummy specimen could then be removed and replaced with a test specimen. A slight vertical adjustment of the oscillating platen could be made to fit the dowel pins through the holes in the grips and the specimen, while axial alignment was maintained. Specimens could be replaced in the grips without realigning the entire grip and fixture assembly.

To prevent buckling of the specimens under compressive loading, stiffeners were used. Spacers were made which could be assembled with the specimen and stiffeners to allow a clearance of .001" to .003" between the specimen and the stiffeners. One stiffener was made with a window through which crack propagation could be observed. Oiled paper was placed between the stiffeners and the specimen to prevent seizing. (The paper was not oiled when the photographic method of determining crack growth was used to avoid oil interfering with the detection of crack growth). Spacers were made to fit the ends of the stiffeners to provide a clearance of .004 - .006" between the grips and the stiffeners during testing. A view of the specimen, stiffeners and grips assembled in the fatigue testing machine is shown in Figure 4.

To check the calibration of the fatigue testing machines, type A-7 and type C-7 strain gages were attached to each side of a test specimen. This test specimen was loaded in a tensile test machine and the calibrations of the strain gages were checked. The test specimen was then put in the fatigue testing machines and calibration checks made for steady loads and

vibratory loads throughout the entire test range. At no point was there more than a 5% difference between load setting and readings obtained from the strain gages.

Equipment For Recording Crack Propagation

On the basis of previous experience (6) it was decided that the data required for the crack propagation studies should be obtained by photographic means. The equipment used consisted of a 70mm roll film sequence camera with a 48mm lens. This camera was equipped with an electric shutter that in turn was operated by a solenoid. Timing of the shutter opening was accomplished by use of an electric timer which could be set by changing gear ratios to open the shutter at a predetermined time interval. When the shutter was fully opened, a switch in the camera closed, operating the flash gun. In series with the flash gun was a contactor which was connected to the main shaft of the fatigue testing machine and which had provisions for changing the position of the contact points in relation to the rotation of the shaft of the machine so that the exposure could be made at a point in the stress cycle where the tension was a maximum and the crack would be opened the maximum amount.

The timing of this contactor to obtain this point of the stress cycle was accomplished by putting a bent specimen in the grips of the fatigue testing machine, setting a light alternating load on the rotating eccentric of the machine, and taking photographs of the specimen at various settings of the contactor which controlled the timing of the flash. The setting of the contactor which produced a photograph of the specimen at its straightest point was used.

The flash unit for illumination had a rating of 1650 ECPS watt seconds and was used at 1/2 power, giving a flash duration of 1/1500 second. Figure 5 shows the camera, light source and specimen arrangement.

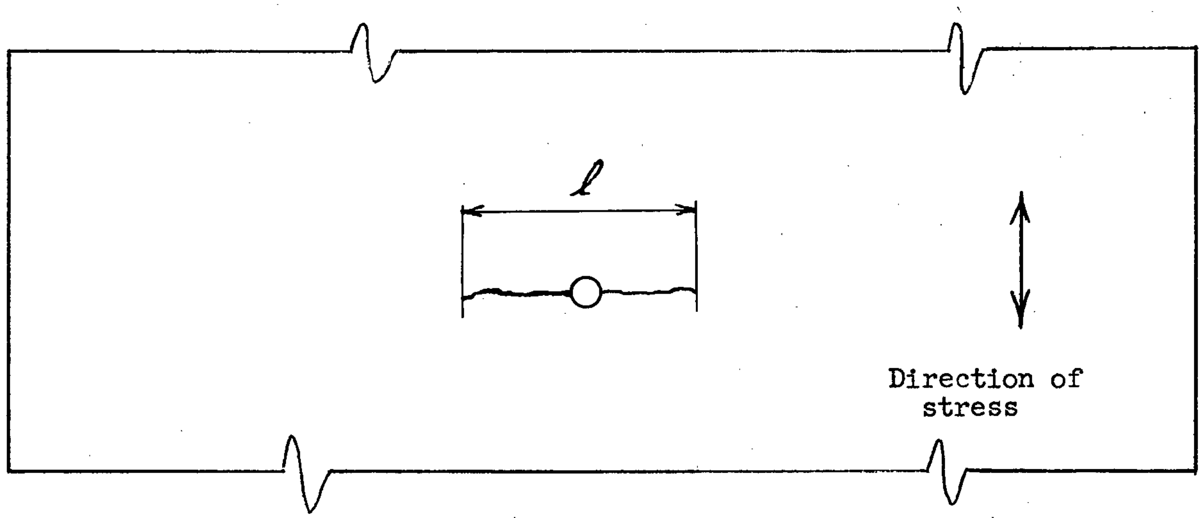
A fine grained panchromatic film with an artificial light rating of ASA 120 was used for all tests and was developed in a high contrast developer in order to obtain a high contrast for ease in reading the crack length. Initial test films were developed in a fine grained developer, but it was found that better results could be obtained with the higher contrast development of the film. Crack length was measured by examining the film with a low power microscope with a micrometer eye piece. The combination of magnification of the camera and the microscope enabled the measurement of crack lengths to the nearest .001". Figure 6 shows a typical sequence of photographs showing crack growth related to cycles of stress.

TEST PROCEDURE AND PRESENTATION OF DATA

Crack Generation

In order to generate a crack at the hole in the specimen, the specimen was cyclically loaded at a level above the fatigue limit of this material with the hole. Several techniques were used to produce the initial hole and to generate the starting crack. The holes in the first specimens were produced by the electro-discharge machining method. The size of the resulting hole varied from 0.0064 inches to 0.015 inches in diameter. While these holes were satisfactory for the large sizes of cracks generated in some specimens, it was considered desirable to use a smaller hole controlled to closer tolerances. A procedure was found for drilling holes of 0.005 - 0.007 inches diameter. With this size hole and in the "as-drilled" condition, it was found necessary to use a stress level of 65 ksi mean stress and ±50 ksi alternating stress to start a crack from the drilled hole. Once started such cracks grew rapidly, however, at this high stress level several failures of the grips were encountered.

By electric etching the edges of the hole on both sides of the specimens, it was found possible to decrease this starting stress level for starting the crack to 60 ksi mean stress and ±40 ksi alternating stress. After a crack was started from the hole, the stress level was then lowered to a level of 50 ksi mean stress and ±30 ksi alternating stress to continue the growth to the desired length. Crack length was determined as the overall length of the crack as shown below.



Method of Measuring Crack Length

Crack length growth was monitored with a binocular microscope as shown in Figure 7 and the cyclic stressing was continued until the desired crack length was obtained. On the initial specimens the crack length observed on only one side of the specimen was recorded. On further observation, it was found that there was some variation in crack length between the two sides, hence on all subsequent specimens the initial crack length was measured on both front and back of the specimen, and both readings were recorded. If significant variations occurred, the crack growth was continued to the 0.095 inch nominal length.

The crack generation histories of each specimen for use in Phase I and Phase II testing are recorded in Table I.

Phase I Testing

The objective in the Phase I program was to determine the fatigue limit (at 5×10^6 cycles) associated with several crack lengths at several mean stress levels. It was initially planned that the testing would be accomplished by the step testing procedure. In this procedure, a specimen was stressed at a specified steady and a specified alternating stress, and the testing was conducted for 5×10^6 cycles. At the completion of this step, the alternating stress level was raised by a given increment and the testing was continued for another 5×10^6 cycles or until failure occurred. If failure did not occur, this procedure was repeated.

The data obtained from such a testing procedure are listed in Table II. It is to be noted that in several instances, specimens which were started at a low value of alternating stress did not fail until several steps had been completed so that the alternating stress had been raised appreciably. However, when other specimens of an identical nature were started at higher levels of alternating stress, failure occurred at a lower stress level than for specimens that had more stress cycles. As specific examples, specimen L-1 was first stressed at 20 ksi mean and ±14 ksi alternating stress. It did not fail. The alternating stress was raised six times in 2 ksi increments and still failure did not occur. The specimen finally failed while being stressed at 20 ksi mean and ±26 ksi alternating after 187,000 cycles. Yet specimen M-14 with a comparable size starting crack was started at 20 ksi mean and ±22 ksi alternating and failed at this stress level after only 99,000 cycles. Several other such examples can be noted in reviewing the data contained in Table II. The explanation for this effect is not known. Possible explanations are (1) the coaxing phenomenon observed in other alloys, (2) scatter in the fatigue behaviour of this alloy and, (3) differences in the residual stress at the tip of the crack in its formation.

Because of this condition it was decided that the step test procedure should be discontinued and all future testing be done at only one stress level per specimen for the Phase I program. In order to increase the amount of data available for the Phase I portion of the program, Phase I and Phase II testing were combined. The results of such tests are recorded in Table III.

The data obtained in Phases I and II and recorded in Tables II and III have been plotted in Figures 8 through 16 as S-N curves for the several mean stress levels and several starting crack lengths used in the investigation. The S-N curves represent the median failure lines. A statistical analysis was performed on the majority of the failure S-N curves and the results of these analyses are also shown on the figures. The standard regression analysis (7) of the median log N values on stress established the 90 percent confidence interval of the average alternating stress (represented by the short horizontal line on the figures), and the 90 percent confidence intervals on the slopes (the dotted boundaries on either side of the upper branch). Only those points representing cycles less than 10^6 were employed in this analysis. The median log N values were weighted by the number of observations.

The horizontal branch of these curves, or the fatigue limits, were obtained by "eye-estimation" since there were insufficient points in this region to perform a statistical analysis. These experimentally determined fatigue limits have been listed in the table on page 18. It is considered that these values are accurate to within about 1.5 ksi (standard deviation).

Phase II Testing

With the aid of the photographic equipment described in the previous section, sequence photographs were taken of the specimens tested during this phase of the program. After development, the films were examined by the use of a low power microscope with a micrometer eye piece. The combination of magnifications of the camera and the microscope enable the reading of crack length to the nearest .001". The syncro-timers on the camera shutter and on the fatigue machine permitted determining the number of stress cycles for each exposure. All exposures were examined and data recorded from significant and typical exposure frames are tabulated in Tables IV through IX. The crack progression for each specimen was plotted on semi-log paper with the crack length on the logarithmic ordinate. Typical examples of these plots are shown in Figures 17 through 19. Most of these curves could be described by four sequential parts: (1) a delay period when no crack growth occurred; (2) a short initiation period where the growth was sporadic; (3) a straight line progression; and (4) an increasing progression rate until failure occurred. Figure 17 is typical of such a behavior.

In some cases there was a break in the straight line portion of the crack progression curve and two slopes were obtained. Figures 18 and 19 are illustrative of cases of a slight change and a marked change respectively. In the tables IV to IX the values of

$$\frac{d \log \ell}{d N} = K$$

are recorded for each specimen and where the crack progression curve showed two slopes, two values of

$$\frac{d \log \ell}{d N} = K$$

are given. These data, with some of the data from Phase III, are summarized in Table X and shown graphically in Figure 20.

Phase III Testing

The Phase III testing program was designed to study stress interactions. It had been initially planned to monitor the crack propagation by periodic visual examination, however, the photographic method developed during the Phase II testing worked so well, it was decided to use this method of recording crack propagation in the Phase III program and thus greatly increase the precision and frequency of the test observations. It had also been planned to test the specimens at three stress levels. Crack generation data for the specimens used in Phase III are recorded in Table XI.

It was considered desirable to have all stress changes occur within the straight line portion of the crack progression curve. For this reason, the test procedure was set-up as follows: (1) test at the first stress level until growth started. The start of growth was verified by microscopic examination from the side opposite the camera (for specimens requiring guide plates, a small hole was made in the guide plate to permit this observation); (2) when growth had started, cycling continued at the same stress level for one-third (assuming a three stress level test) the number of cycles of life expected in the straight line portion of the crack progression curve (determined from Phase II); (3) change the stress level and cycle for one-third the number of cycles of life expected in the straight line portion of the crack progression curve for that stress level; (4) change the stress level and test to failure. This test was conducted on four specimens with a gross mean stress of 40,000 psi and gross alternating stresses of ±8,000 psi, ±10,000 psi, and ±12,000 psi. The results of this testing are tabulated in Table XII. In no case was there any measurable delay in crack growth after a change in stress and the values for

$$\sum \frac{n}{N}$$

for the four specimens were .710, .796, .868, and 1.04. These values were considered close enough to the theoretical value of 1 to indicate no stress interaction within this stress range.

It is possible that no stress interaction is indicated because the change of alternating stress level is relatively slight.

It was known from Hudson and Hardrath (8) that cracks generated at high stress caused delay at low stress for aluminum. In order to determine this effect on the titanium alloy being used in this program, cracks were grown from 0.095" nominal length to approximately 0.115" at a gross mean stress of 40,000 psi and gross alternating stresses of ±30,000 psi, ±20,000 psi, and ±15,000 psi. The alternating stress was then dropped to ±8,000 psi and the progression monitored. From Tables XIII and XIV it can be observed that the higher stresses used to grow the cracks resulted in a greater delay in the start of crack growth at the ±8,000 psi alternating stress than did the lower stresses.

The results of this preliminary testing indicated that the major stress interaction effect was a delay in crack growth which varied with the stress applied to the crack immediately before testing at a lower stress. Therefore, the remainder of the Phase III testing was performed in such a manner as to establish the effects of variations in a high first stress upon the delay in growth at a lower second stress.

Specimens which had nominal crack lengths of 0.042" and 0.095" generated at 50 ksi ±30 ksi were placed in the test machine and the cracks were grown approximately 20 percent at mean stresses of 0, 20, and 40 ksi and various alternating stresses. During such stress cycling, crack length was monitored and crack length measured until the desired growth was obtained. When the desired growth was obtained, the alternating stress level was lowered and progression of the crack was monitored photographically until failure occurred or until a very large number of cycles (over 200,000) indicated no growth was taking place. If examination of the latter specimens confirmed that no growth took place, the alternating stress was increased and the test re-run. If no growth occurred after a large number of cycles at the new stress level, the testing of that specimen was abandoned.

The complete history of each specimen, including first stress, second stress, crack progression and crack progression rate is shown in Tables XV through XX. The delay cycles are tabulated in Tables XIII and XIV. Crack lengths tabulated are all from the camera side.

The data from Tables XIII and XIV are plotted in Figures 21 through 26. Also plotted in these figures is the delay data from Phase II (Table III) where the first stress was considered equal to the generating stress, 50 ±30 ksi. Straight line plots through points of equal first stress were drawn by eye for each mean stress and starting nominal crack length. Each nominal starting crack length at each mean stress then had a family of four roughly parallel delay cycle S-N curves, one from the delay cycles determined in Phase II, and three from delay cycles determined in Phase III.

ANALYSIS OF TEST RESULTS AND DISCUSSION

The Critical Dynamic Crack Length and Stress (Fatigue Limit Associated With A Crack)

Fatigue cracks that do not propagate with continued cyclic stressing have been reported by several investigators. Non-propagating cracks have been observed at the root of notches and on precracked specimens (9), (10). Also, non-propagating micro-cracks (11) have been found in smooth specimens tested slightly below the fatigue limit of the material.

A simple relation (12) between the fatigue limit associated with a crack and its length when the mean stress is zero has been suggested as follows:

$$s_f^{\beta} \ell = C \qquad (1)$$

In a number of investigations on different alloys, the National Engineering Laboratory (12) has found that the the exponent, β , is equal to three. In order to eliminate the possible effect of residual stresses at the tips of the cracks, all specimens in their tests were heat-treated or stress-relieved after the crack formation.

In a recent investigation, Duckworth and Ineson (13) of the British Iron and Steel Association have demonstrated the relation of the critical dynamic crack length to the sizes of the non-metallic inclusions in steel. In this investigation, the authors introduced various shapes and sizes of inclusions into the steel.

However, there are two major questions that must be answered before this relation can be applied in practice:

(1) What modification of formula (1) is necessary to account for mean stresses other than zero?

(2) How do the stress conditions (mean and alternating) employed to generate the crack modify

this relation if the specimen is not heat-treated or stress-relieved after the crack generation?

One simple modification of equation (1) for the mean stress of the test is:

$$(1 + b\, s_m)\, s_f^{\beta}\, \ell = C_1 \tag{2}$$

However, the above form did not give a reasonable fit with the experimental data listed in the table below.

Another relation that was tried is in the form:

$$(s_f + b_f\, s_m - s')^3\, \ell = C \tag{3}$$

In this empirical formula, the quantity, s' , is related to the stress conditions used to generate the crack.

Fatigue Limits Associated With Cracks
Generated at 50 ± 30 ksi

Mean Stress s_m - ksi	Nominal Crack Length In.	Estimated Experimental Fatigue Limit, ksi	Calculated Fatigue Limit ksi
0	0.020	36.5	36.5
0	0.042	33.6	34.3
0	0.095	32.4	32.4
20	0.020	23.5	24.3
20	0.042	22.0	22.2
20	0.095	21.6	20.2
40	0.020	13.5	12.1
40	0.042	10.6	9.9
40	0.095	5.8	8.1

The parameters in equation 3 were obtained by standard regression analysis (least square fit). The parameters were found to be as follows:

b_f = 0.608

C = 20.1

s' = 26.46 ksi

The fatigue limits associated with the two crack lengths were then computed by means of formula 3, employing the parameters on page 18. The root-mean-square error of these computed fatigue limits is ±1.08 ksi. The test values and the computed values are plotted in Figure 27.

Several investigators (14),(15) have suggested that a discontinuity exists in the fatigue phenomena if part of the stress cycle is in the compressive range (i.e., $R < 0$) since the closure of the crack during this part of the cycle creates a stress field that differs in form from that in the tensile part of the cycle. It has been suggested (14) that only the tensile part of the cycle is effective in fatigue, particularly in crack propagation. A more general hypothesis, however, is that a fractional part, γ, of the maximum compressive stress in the cycle should be considered.

This suggestion leads to a method of correcting the gross alternating and mean stresses when $s_a > s_m$, or $R < 0$. These corrected stresses are:

$$s'_a = \frac{(s_a + s_m) + \gamma (s_a - s_m)}{2} \qquad (4)$$

$$s'_m = \frac{(s_a + s_m) - \gamma (s_a - s_m)}{2} \qquad (5)$$

The computed values in the table on page 18 were based on the assumption that $\gamma = 1$. However, additional computations for γ between zero and unity showed that the proposed relation was not sensitive to this factor from about 1/2 to 1. When $\gamma = 0.5$, the following parameters were obtained:

$$b_f = 0.522$$

$$C = 9.72$$

$$s' = 25.0 \text{ ksi}$$

The rms error of s_f in this case was ±1.56. Since this error is not significantly different from the previous value (±1.08), a γ value of 0.5 is considered reasonably correct.

Crack Propagation

Many formulas have been proposed in recent years for predicting the rate of crack propagation in a sheet or bar subjected to a uniform alternating fatigue stress. Two general approaches (16, 17) will be considered in this report.

In 1946, Bennett (17) of the National Bureau of Standards reported that, in the growth of a fatigue crack in X4130 steel, the logarithm of the crack length* was a straight line when plotted against the number of cycles. This observation is mathematically described in the differential form by:

$$\frac{d \log \ell}{d N} = \frac{d \ell}{\ell \, d N} = K \qquad (6)^{**}$$

Bennett found that this slope increased rapidly with the imposed stress level.

This relation was independently observed by this laboratory (18) and at about the same time it was also proposed by Frost and Dugdale (19). One of the simplest assumed relations of K to stress is a power function of alternating stress. For the case of pure alternating stresses, this relation is described in the integral form by:

$$\log \frac{\ell}{\ell_o} = k \, s_a^{\alpha} \, (N - N_o) \qquad (7)$$

where ℓ_o and N_o are the constants of integration.

Researchers at the National Engineering Laboratory (14) have conducted extensive tests on many alloys, and have determined that the stress exponent is equal to 3.0, at least, in all alloys that were tested. Further, it has been found that the above relation is valid only for crack lengths less than about 15 percent of the sheet width, the exact length depending on the level of the alternating stress.

At least in one alloy (20), the rate of propagation was found to be independent of the plate thickness of the specimen when it was changed from 0.128 to 1.0 inch.

There are several relatively simple empirical modifications of the above relation to allow for a superimposed mean stress, s_m. These suggested forms are:

---

* Actually Bennett subtracted a small initial length of crack to obtain the linear log ℓ vs N plot of crack propagation.

** This relation is valid if the natural logarithm is employed, otherwise there is the factor, $\log_a e$, that modifies this.

$$\log \frac{\ell}{\ell_o} = k_1 (1 + b_1 s_m) s_a^{\alpha} (N - N_o) \tag{8a}$$

$$\log \frac{\ell}{\ell_o} = \frac{k_2}{1 - b_2 s_m} s_a^{\alpha_2} (N - N_o) \tag{8b}$$

$$\log \frac{\ell}{\ell_o} = k_3 (s_a + b_3 s_m)^{\alpha_3} (N - N_o) \qquad (8c)\ *$$

The first modification (8a) was proposed by Frost (21), while the other two (8b and 8c) have been suggested by the present authors. Of engineering interest is the fact that the data reported in reference (21) show that the crack propagation rate is relatively insensitive to the gross mean stress in austenitic and mild steels but is very sensitive to the mean stress in aluminum alloys.

The values** of $K \times 10^6$ which is the initial slope of the $\log \ell$ versus N curve for this alloy have been recorded in Tablex IV to IX and XV to XX inclusive. These data have been systematically summarized in Table XXI (fourth column).

There appeared to be three classes of curves of crack propagation when the crack was less than about 15 to 20 percent of the width of the specimen. The most common type of curve is a single straight-line relationship of the logarithm of the crack length versus the number of cycles. This is illustrated in Figure 17. In the second class, two straight line segments of slightly different slope were observed. This is illustrated in Figure 18. In Table XXI, these two slopes have been recorded separately. In most of these cases, the average of these two slopes is recorded in the fourth column and is employed in the analysis. A third class, shown in Figure 19, is that when the initial slope was very small in relation to the second slope. In this case only the latter was used. In a total of about 100 specimens, this only happened in four cases. The reason for this peculiar behavior is not known.

The geometric mean of $K \times 10^6$ computed for each stress condition is listed in Table X. These data were employed in deriving the best-fit for each of the suggested relations for K (factors in equation 8):

---

* This relation is theoretically incorrect when $s_a \rightarrow 0$.

** In the computation of this slope, the logarithm to the base 10 was used rather than the natural logarithm.

$$K = k_1 (1 + b_1 s_m) s_a^{\alpha_1} \quad (9a)$$

$$K = \frac{k_2}{1 - b_2 s_m} s_a^{\alpha_2} \quad (9b)$$

$$K = k_3 (s_a + b_3 s_m)^{\alpha_3} \quad (9c)$$

The statistical analysis accomplished on a digital computer for paired values of α and γ was made to determine the optimum values of the parameters. This was accomplished by the conventional regression analysis (22). The value of α was varied between about 2.2 and 3.2, while the values of γ that were chosen were 0, 0.20, 0.50, 0.75 and 1.0.

For each paired value of α and γ, the optimum value of the parameters, k and b, were established. For each combination of α, γ, b and k, the value of K was computed for each stress level using the appropriate formula. The differences between this computed value and the corresponding experimental value determined the root-mean-square error.

These rms-errors* have been plotted in Figures 28, 29, and 30, as functions of α and γ. The overall best-fit was taken to be that point corresponding to the minimum error. These errors have been tabulated in the table below.

Value of the Parameters For Equations 9a, 9b, 9c For Ti - 8 Al- 1 Mo- 1 V Alloy

Formula	α	γ	k x 10^6	b	Errors in K x 10^6 (rms error)
9-a	2.05	.49	.058	.0100	6.08
9-b	2.58	.61	.00751	.0174	4.75
9-c	2.75	.43	.00615	.1022	4.8

The goodness-of-fit may be judged by comparing the rms error to the average K of all tests which is 32.3.

* rms-error = root-mean-square error.

The data of Liu (23) on 2024-T3 material were similarly analyzed to check the above trend. In the investigation conducted by Liu, all test conditions were in the tensile range so no adjustment was required for crack closure. The error between the observed and calculated values of K (rms error) have been plotted in Figure 31. The best fits (based on minimum rms error in K) have been tabulated in the following table where the superiority of equations 9b and 9c is to be noted.

Values of the Parameters For Equations 9a, 9b and 9c For 2024-T3 Aluminum Alloy

Formula	α	k x 10^6	b	Error in K x 10^6 (rms error)
9-a	2.36	0.157	-0.0144	12.6
9-b	2.80	0.016409	0.02232	5.0
9-c	3.74	0.000825	0.234	4.2

However, because of the significant scatter in the test data of the Ti-8-1-1 alloy as well as in the aluminum alloy tested by Liu, and because it was found that the errors between the observed and calculated values of K in equations 9-b and 9-c changed rather slowly with changes of the exponent, α , in the vicinity of 3, it is believed that the value $\alpha = 3$ reported in the literature is a reasonable value. This is to be seen in Figures 28 through 31 inclusive and in the following table:

Values of the Parameters for $\alpha = 3$

Material	Equation	γ	k	b	Error in K x 10^6 (rms error)
Ti 8-1-1	9-b	0.615	0.00181	0.0217	6.49
"	9-c	0.463	0.00269	0.1223	6.43
2024-T3	9-b	- -	0.00946	0.0229	5.72
"	9-c	- -	0.00908	0.1768	6.54

The reason for the significant scatter in the experimentally determined values of K is not known. It was found in the course of this investigation that the following factors had no effect:

(1) Change in the humidity during the test period.

(2) Errors in the values of the alternating and mean stress.

The material supplier has suggested that the specific heating, rolling and heat-treatment sequences used may tend to develop a preferred crystallographic orientation. If this preferred orientation was only partially developed, and if crack propagation were sensitive to orientation, this may be a possible explanation for some of the scatter in test results. A further investigation of this possibility is suggested. An analysis of several random samples having both slow and fast crack propagation rates has shown that crack propagation rates during generation of the cracks gave high correlation with the rates during subsequent testing while testing under phases II and III. This would seem to give further credence to the possibility of local metallurgical differences that influence crack propagation. A study of specimen location within the original sheet versus fatigue properties and crack propagation rates obtained, showed no evidence of gross areas with significantly different results.

Another general approach to the mathematical formulation of the crack propagation rate is that described in references (16, 24, 25 and 26). In this method, the Neuber hypothesis that the material behaves at the tip of cracks or at the root of notches in a manner to blunt the sharpness of the crack tip is assumed. That is, the material at the microscopic level is assumed to behave uniformly over a small region; the characteristic size of this is called the Neuber constant, ρ'. In this approach, the effective stress at the crack tip is computed by considering this blunting effect. On this basis, the rate of crack propagation is considered to be a function of this effective stress. The semi-empirical formula proposed in reference (16) is:

$$\log \frac{d\,\ell}{d\,N} = A\,K_N\,s_{net} + B + C\,\frac{s_f}{K_N\,s_{net} - s_f} \qquad (10)$$

where A, B, and C are material parameters, and s_f is the fatigue limit of the unnotched material.

Since in its present form, this method (reference 16) is strictly applicable to one R-value and since there were only sufficient experimental data generated in this current program at R = -1 for correlation with equation 10, only these data were used for this purpose. Unfortunately, the other experimental data of this program were not replicated at other constant R-values. The crack lengths selected for this correlation were in the range of 0.040 inches to 0.160 inches. The regression analysis (22) of this limited experimental data resulted in the following values for the constants:

$$\rho' = 0.01749$$

$$A = 0.016213$$

$$B = -6.54121$$

$$C = -1.8492 \times 10^{-5}$$

Here the ρ'-value was selected to be the largest that would not allow a discontinuity to arise from the last term in equation (10).

The corresponding rms-error in $K \times 10^6$ for the relation of the equation (10) was computed to be 9.68, compared to 7.11 and 7.45 for formulas 9-b and 9-c respectively for this specific case of R = -1.

Analysis of Delay - Cycles

Each "delay S-N" curve (see Figures 21 through 26) displays the number of cycles required to re-initiate crack growth at a specific alternating and mean stress level after the crack had been grown to a specific length at a prior alternating and mean stress level (designated on each curve). An examination of each figure shows a strong correlation in the position of each delay S-N curve with the prior alternating and mean stress level associated with it. An increase in either the prior alternating stress or the mean stress increases the number of delay cycles. In the next paragraphs, a quantitative analysis of this apparent relationship is presented.

For this purpose, the test alternating stresses of the delay-cycle curves corresponding to 10^4 cycles were obtained from these figures. A value of 10^4 cycles was selected since this value was in the middle of the observed values of delay-cycles. These data were recorded in Table XXII, and were statistically analyzed to establish whether a correlation between the test stress condition and the prior stress condition existed.

For this correlation study it was assumed that an equivalent test stress was related to an equivalent stress employed to generate the crack to the specified length. The effective test stress was defined to be equal to the test alternating stress corresponding to 10^4 delay-cycles plus a fractional part of the mean test stress, or

$$s_{e_1} = s_a' + b_d\, s_m' \qquad (11)$$

and the prior effective stress was defined by a similar relation,

$$s_{e_2} = s_a' + b_p\, s_m' \qquad (12)$$

In these equations, the primes indicate that the correction of the stresses during crack closure described by equations (4) and (5) has been used.

The data presented in Table XXII were analyzed by the simple "quadrant-sum" correlation test described in reference (27). The hypothesis was assumed that those specific values of the parameters, γ, b_d and b_p, that gave the highest quadrant-sum between the equivalent test stress and the equivalent prior stress were optimum. The accuracy of the test data did not warrant a more sophisticated statistical technique.

In this analysis, the value of each parameter was varied independently from zero to unity. The selected values for each were 0, 0.25, 0.50, 0.75, and 1.0. For each combination, the equivalent test and prior stress values were plotted on linear graph paper for each crack length (nominally, 0.042 in. and 0.095 in.). The quadrant-sums of the two crack lengths were computed and averaged. There were 250 combinations of the parameters that were evaluated by the quadrant-sum test, or 125 average quadrant-sums.

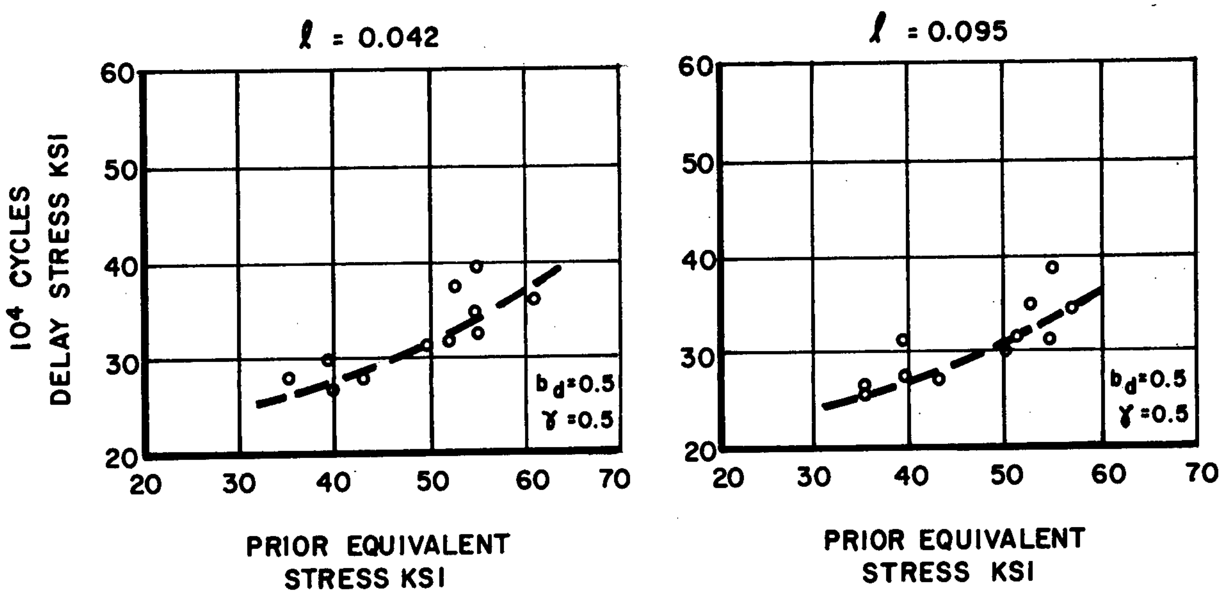
The highest quadrant-sum was found when the parameters had the following values:

$$\gamma = 0.5$$

$$b_p = 0.5$$

$$b_d = 0.5$$

The quadrant-sum for this combination was 24, which corresponds to a very high correlation. The graph for this combination is shown in the figure on page 27. Combinations, in general, resulted in significantly lower quadrant-sums. For example, when $b_p = b_d = 1.0$, the value was only about 9.5 for all values of γ.



Correlation of equivalent stress for 10^4 delay-cycles with the equivalent stress for the crack formation

It should be noted that the above value of the equivalent stress coefficient, b, is about the same as that obtained for the fatigue limit of a crack (see page 19). Further, the optimum value of γ is the same for crack propagation, the fatigue limit of a crack, and the delay-cycles.

A Suggested Cumulative Fatigue Damage Relation

High-performance structures and machine elements are often subjected to spectra of random load levels in service in which part of the spectrum induces cyclic stresses that exceed the so-called "fatigue limit" of the material. In these cases it is necessary in the design stage to estimate the probable fatigue life of the component. In the development of a cumulative fatigue damage relation it is necessary to distinguish between the crack initiation stage of smooth laboratory specimens and that of full-scale components that usually contain highly localized flaws or other localized stress-raisers. In this latter case, the initiation stage is usually small relative to the total cycles to failure. Further, the extreme maximum values of the spectra are likely to be in that portion of the S-N curve where the initiation stage is relatively small in relation to the total fracture cycles. That is, the crack propagation stage is likely to start at a low cycle-ratio. Therefore, in a high-performance structure or machine element, it will be assumed that the fatigue life is largely associated with the propagation of an initial micro-crack.

One type of crack propagation formula (equation 8) is of the form:

$$\log \frac{\ell}{\ell_o} = K(s_a, s_m)(N - N_o) \quad \text{.......................(13)}$$

or

$$\log \frac{\ell}{\ell_o} = K(s_a, s_m)\, n \quad \text{..............................(14)}$$

where n is the number of cycles counting after the crack has attained the small initial length, ℓ_o. For n cycles at the stress condition, s_{a_1}, s_{m_1}, the final length of the crack is equal to:

$$\log \frac{\ell_1}{\ell_o} = K(s_{a_1}, s_{m_1})\, n_1$$

If the stress level is changed to s_{a_2}, s_{m_2}, for n_2 cycles, the crack length is found by the relation:

$$\log \frac{\ell_2}{\ell_1} = K(s_{a_2}, s_{m_2})\, n_2 \quad \text{............................(15)}$$

where n_2 is the number of cycles at this second stress level. In this relation it has been assumed that there is no stress interaction, i.e., there are no delay-cycles at this stress level.

Similar relations are obtained for other subsequent stress conditions in the histogram. If all such equations are summed:

$$\log \frac{\ell}{\ell_o} = \sum_{i=1}^{i=j} K(s_{a_i}, s_{m_i})\, n_i \quad \text{.....................(16)}$$

where ℓ is the final crack length.

A reference condition may be chosen to be equal to one of the highest stress conditions in the histogram or stress spectrum. The length of crack at this condition that causes catastrophic failure of the structure will be designated by ℓ_r, and the number of cycles corresponding to this length of crack, N_r, for constant stress testing at this reference condition. This relation is:

$$\log \frac{\ell_r}{\ell_o} = K(s_{a_r}, s_{m_r})\, N_r \quad \text{.............................(17)}$$

"Fatigue Damage" will be defined to be the ratio of these equations or:

$$D = \frac{\log \frac{\ell}{\ell_o}}{\log \frac{\ell_r}{\ell_o}} = \sum_{i=1}^{i=j} \frac{K\,(s_{a_i},\ s_{m_i})}{K\,(s_{a_r},\ s_{m_r})} \quad \frac{n_i}{N_r} \tag{18}$$

If the relation (8-c) is substituted into the above, then:

$$D = \frac{\log \frac{\ell}{\ell_o}}{\log \frac{\ell_r}{\ell_o}} = \frac{1}{N_r} \sum_{i=1}^{i=j} \Phi \left(\frac{s_{a_i} + b\ s_{m_i}}{s_{a_r} + b\ s_{m_r}}\right)^{\alpha} n_i \tag{19}$$

The function, Φ , is the stress interaction function and may be either zero or unity (or possibly greater than unity). It is unity if there is no delay in the crack growth when the stress condition is changed from a previous value. It is zero if there is a delay in crack propagation, the number of delay cycles depending on the previous history of stresses as well as the current stress level. Whether or not a previous stress condition can exist that accelerates the crack growth is not known. If this does occur, then this stress interaction function will exceed unity. Conceivably this could occur if one or more large compressive half-cycles were present in a spectrum wherein the other stresses were in the tensile range.

In this current investigation it has been shown that this quantity Φ is a function of the current equivalent stress level $(s_a + b\ s_m)$ as well as the prior equivalent stress level. This investigation has been limited to the case wherein the prior stress level has been conducted for a sufficient number of cycles to establish a quasi-equilibrium state. The case of one-half cycle or a small number of prior stress levels on the delay-cycles at another stress condition is yet to be explored.

In a spectrum of random stresses this function may be assumed equal to unity on the basis that the change in stress levels is not sufficiently large to cause any significant delay. This assumption would underestimate the fatigue life.

It is to be noted that when the mean stress is zero in the above cumulative fatigue damage formula, this formula becomes identical to that proposed by Corten and Dolan (28). The Corten-Dolan theory gave excellent correlation with test results on four different alloys using various types of complex stress histograms, or spectra (29), (30). Over 5000 specimens were used in the investigation of reference (30).

However, this latter investigation was conducted on thin wires and indicated that the stress exponent, α , was in the order of 5.8 (instead of 3.0 found in this current work). It is suggested that this difference

in the exponent is caused by the high stress gradient inherent in the bending tests on thin wires.

CONCLUSIONS

This investigation attempts to explore the variables that influence the fatigue limit associated with a crack; to evaluate the parameters in several crack propagation formulas; to investigate some of the factors that influence the stress interaction effect on crack propagation and to investigate how the delay-cycles may be taken into account when a spectrum of imposed stresses is involved. An attempt has also been made to consolidate the findings from the several phases of the study into an integrated approach to the Cumulative Fatigue Damage problem. It should be cautioned that the conclusions reached are based on test data obtained from a Ti - 8 Al - 1 Mo - 1 V alloy, and while it is believed that the theories can be applied to other alloys, more extensive testing and evaluation of material constants are necessary. The following points summarize the major results and conclusions that were obtained by statistical analysis of the test data:

pg ~~35~~ to p 51

1. Because of a probable discontinuity in the form of the stress field around the tip of a crack when crack closure exists during the compressive part of a cycle, it was found necessary to introduce a correction factor (the γ factor). This correction factor was found to be about 0.4 to 0.5 from the statistical analysis of: (1) the delay-cycles, (2) the crack propagation rates, and (3) in the fatigue limit associated with a crack.

2. All phenomena investigated in this program indicated that an equivalent stress equal to the gross alternating component plus a fractional part of the gross mean stress was a simple, and reasonably accurate, independent variable for describing these phenomena.

3. The fatigue limit associated with a crack was found to be represented reasonably accurately by a simple formula. (Equation 3).

4. The analysis of these test data suggests that this fatigue limit is dependent on the stress level used to start the crack.

5. Several suggested empirical, or semi-empirical, formulas gave good correlation with the rates of crack propagation found for this alloy. (Equations 8-b and 8-c).

6. In two proposed relations (equations 8-b and 8-c) the experimental value of K could not be determined with a high degree of precision because of the sparcity of data and scatter of test data. Hence a precise value for the stress exponent, α , could not be determined. The value of 3.0 suggested in the literature appears to be reasonable.

7. In the Neuber type relation for crack propagation rate (equation 10), the correlation was limited to a restricted number of test points because of the nature of the test program. A reasonable correlation between the proposed relation (10) and the limited experimental data was found to exist.

8. In the study of stress interaction effects, it was found that there existed a high correlation between the equivalent stress corresponding to the first stress condition and the equivalent stress in the second stress condition for 10^4 delay-cycles.

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33. Hudson, C. Michael; and Hardrath, Herbert F.: Investigation of the Effects of Variable Amplitude Loadings on Fatigue Crack Propagation Patterns. NASA TN D-1803, 1963.

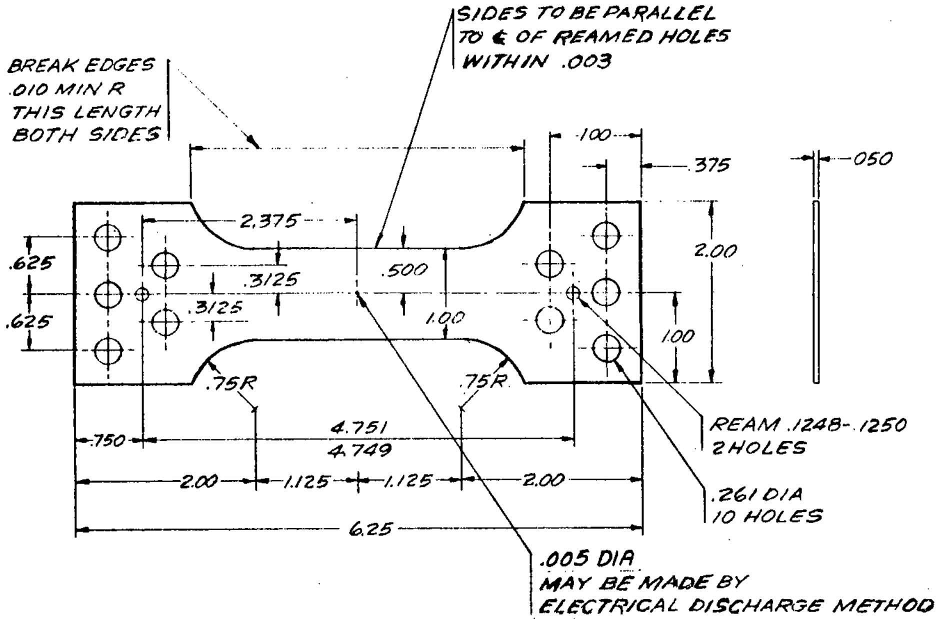

Figure 1. Axial fatigue specimen.

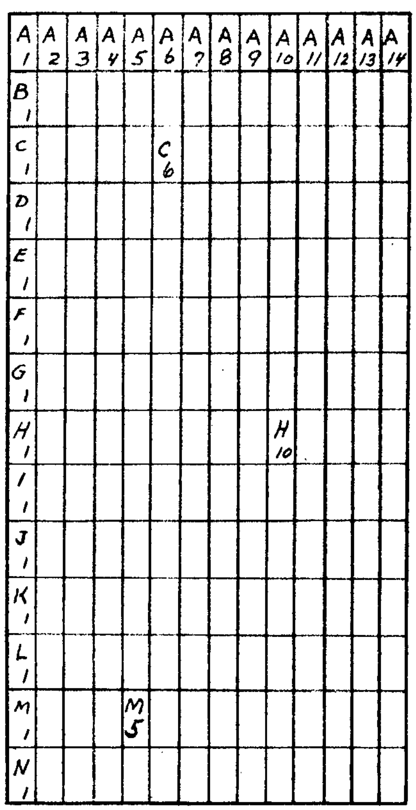

Figure 2. Location of specimens in sheet.

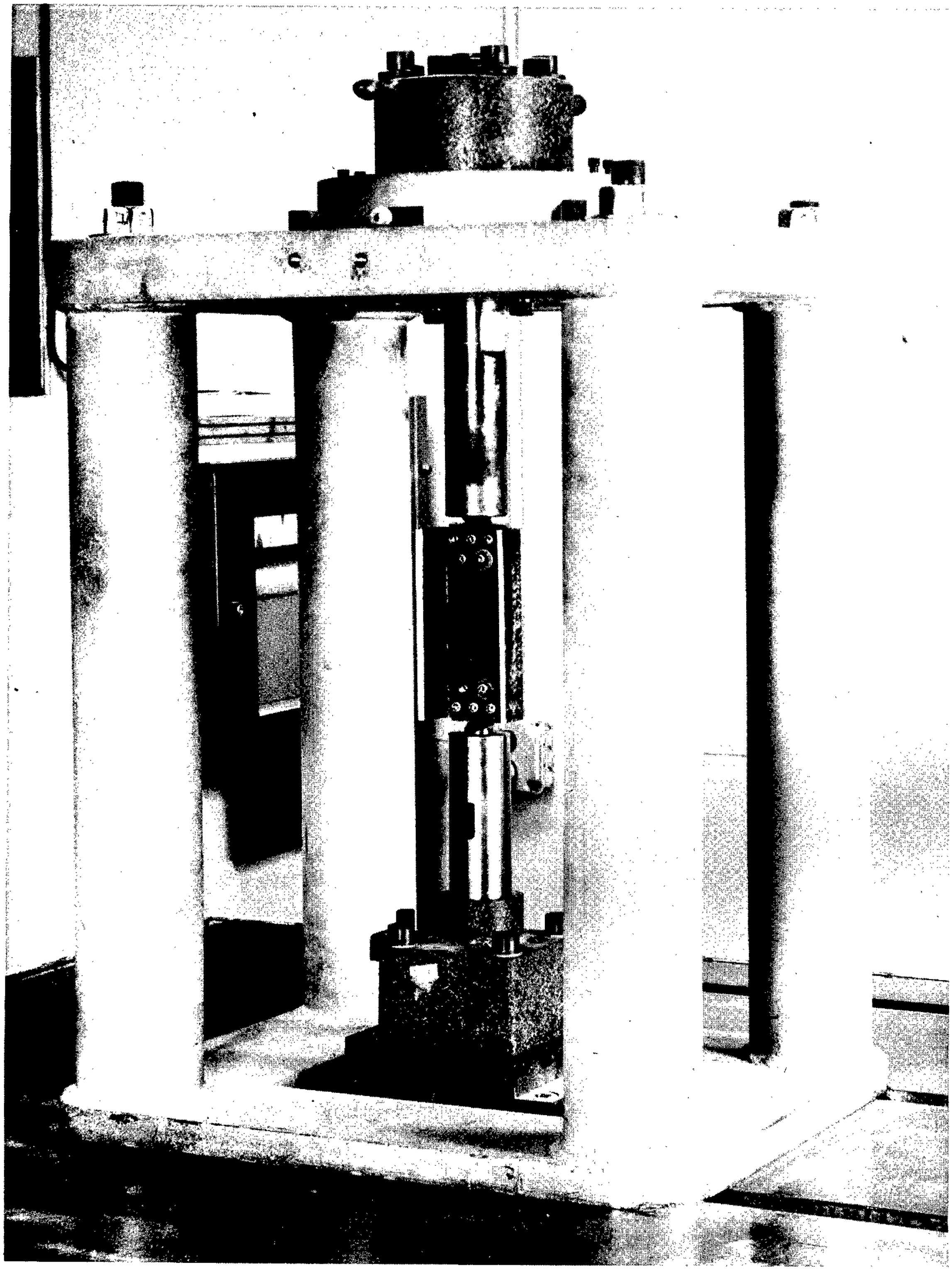

Figure 3. Dummy specimen and grips assembled in fatigue testing machine.

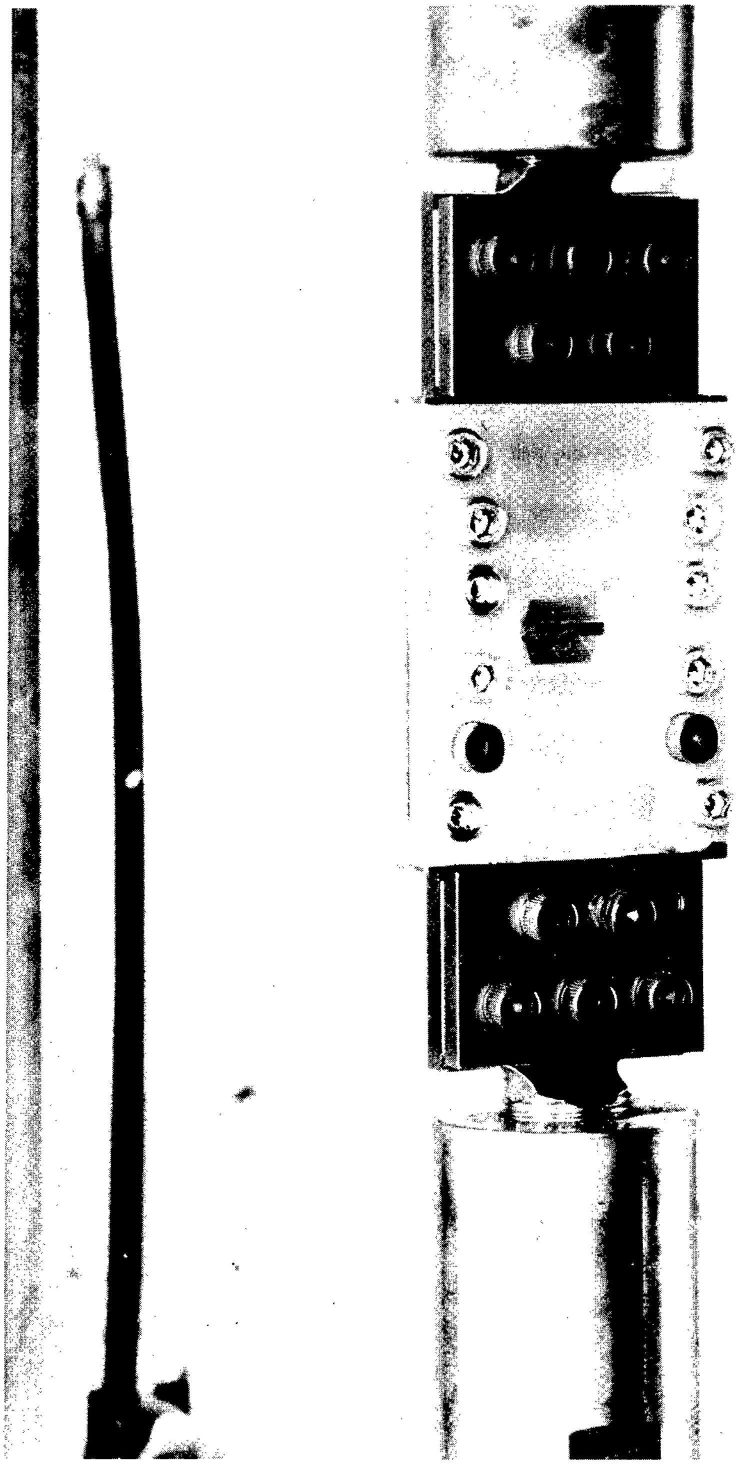

Figure 4. Specimens and stiffeners assembled in grips in fatigue testing machine. Window in stiffener permits measurement of crack progression.

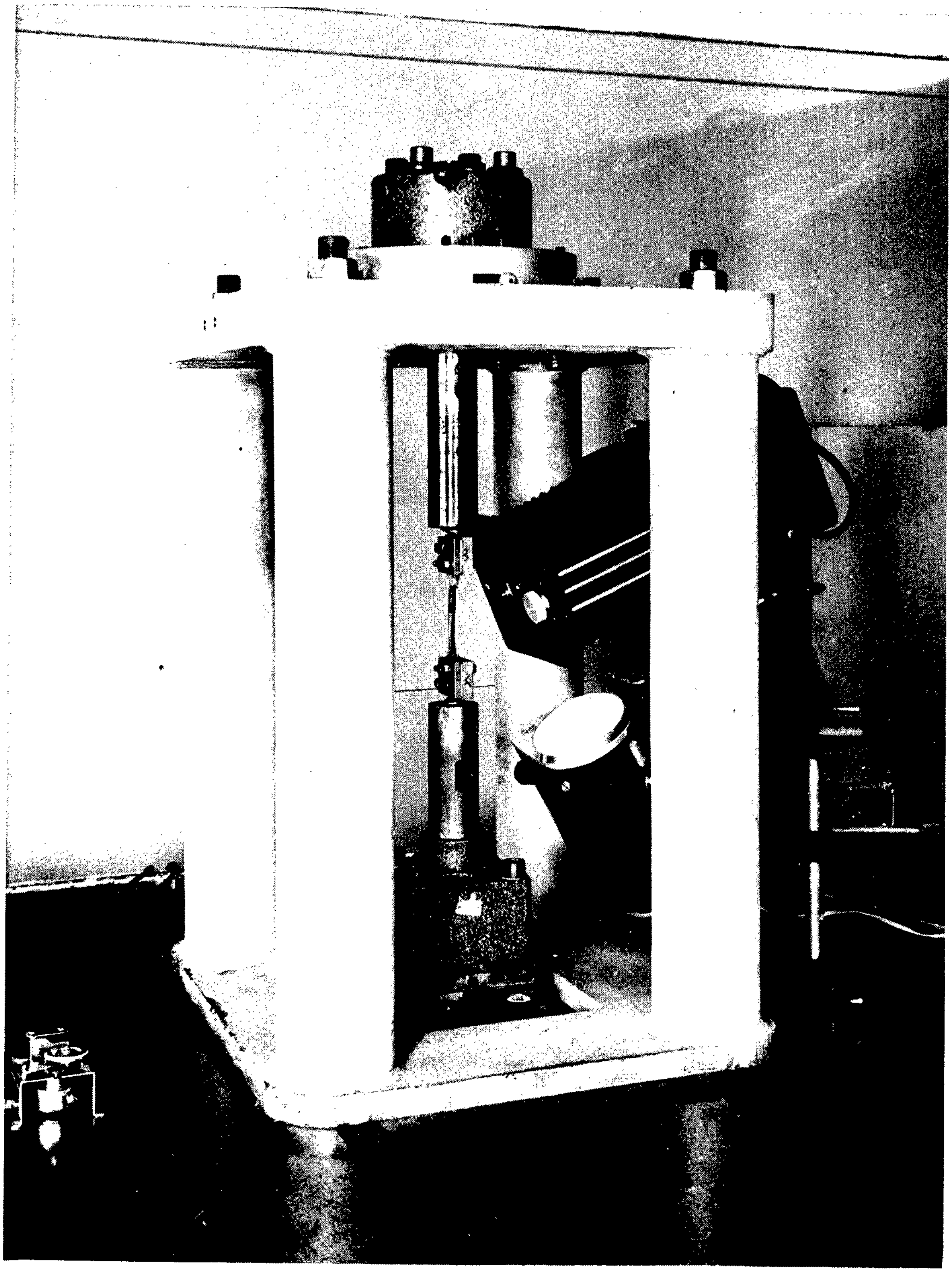

Figure 5. Fatigue testing machine with specimen in place. Camera and electronic flash gun in position to monitor crack growth. Electrical timing device can be seen at lower left.

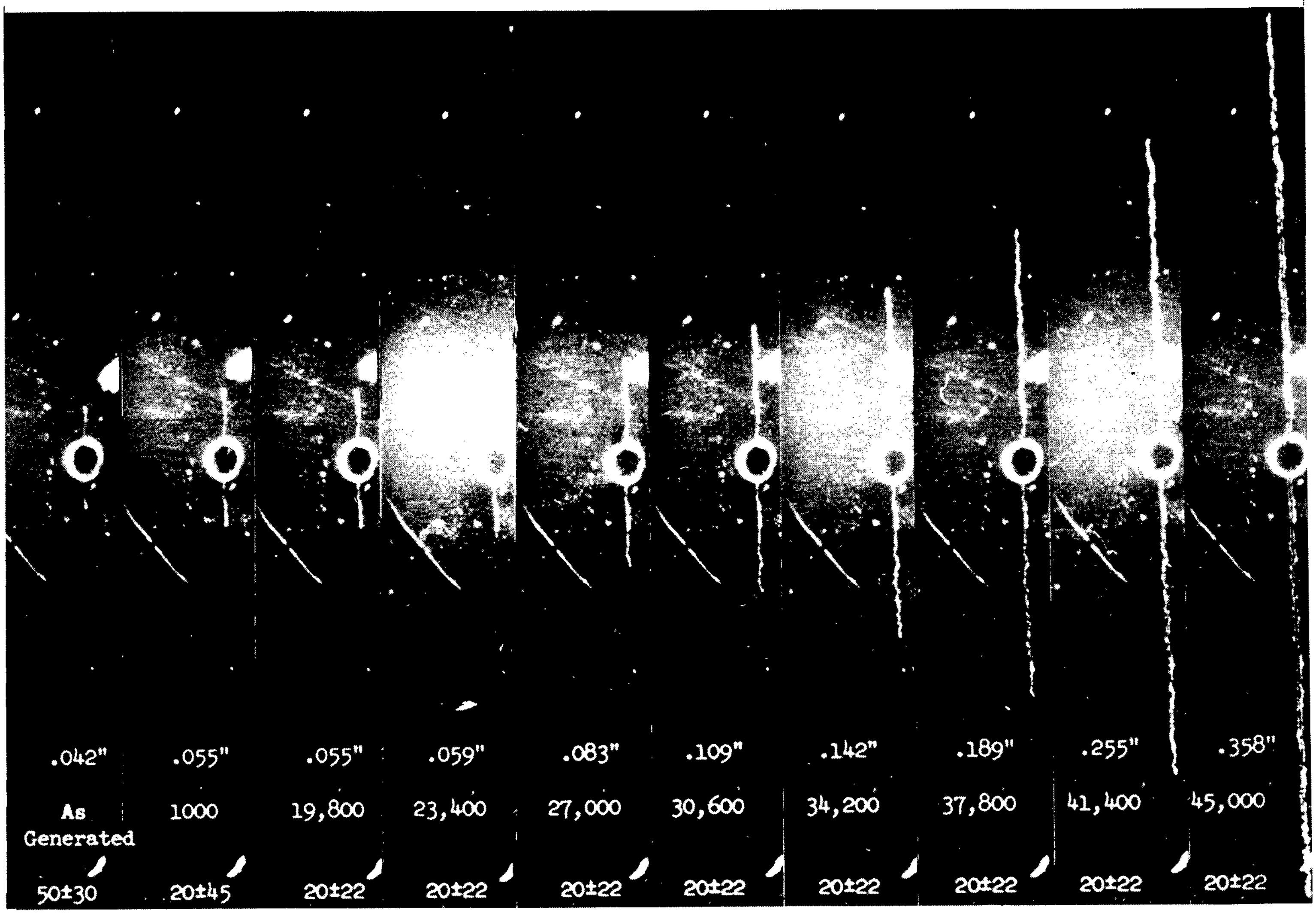

Figure 6. Composite photograph illustrating typical result from photographic method of measuring crack progression. Specimen I-12, Phase III, failure occurred 5000 cycles after photo at extreme right.

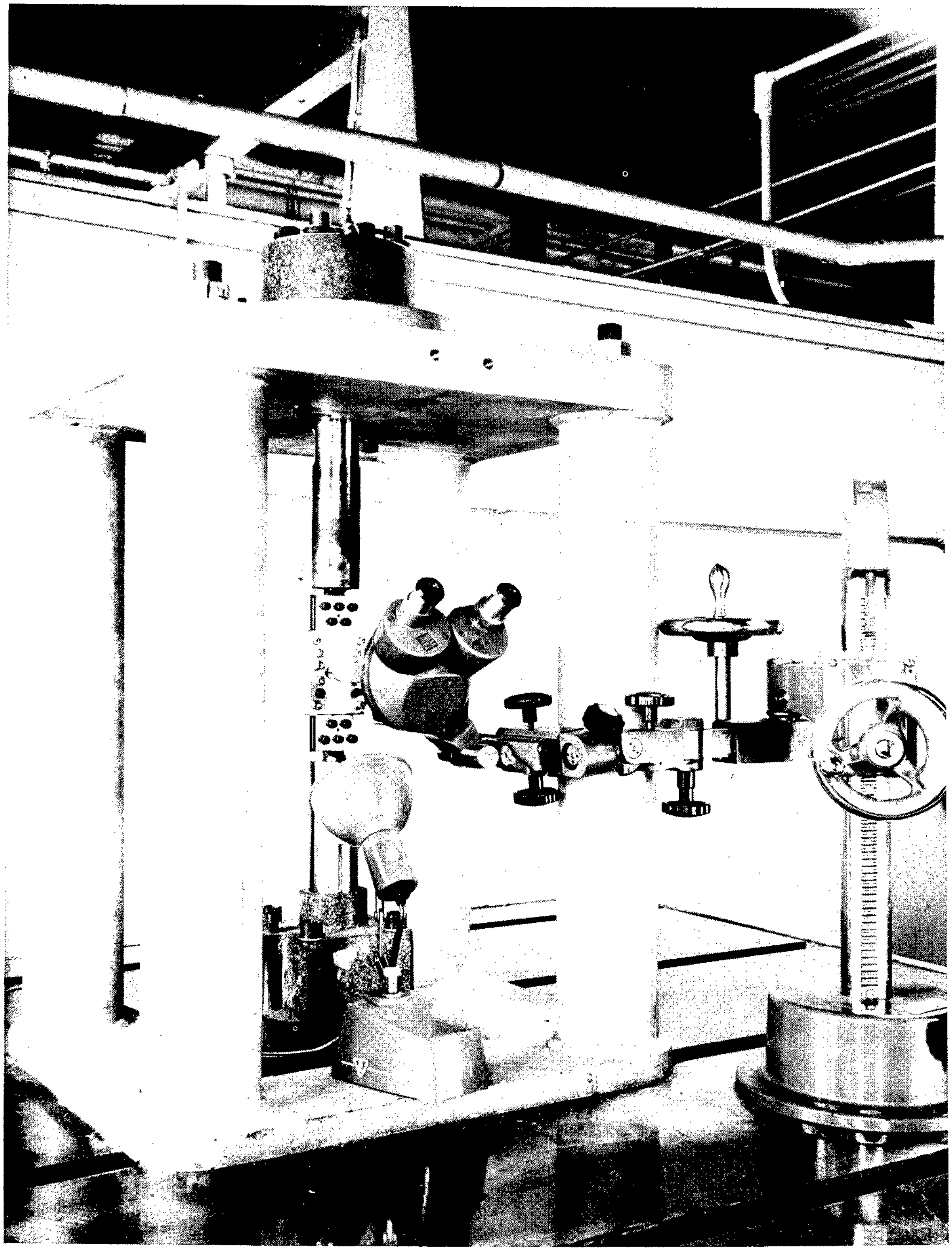

Figure 7. Fatigue testing machine with specimen in place and microscope in position to monitor crack growth.

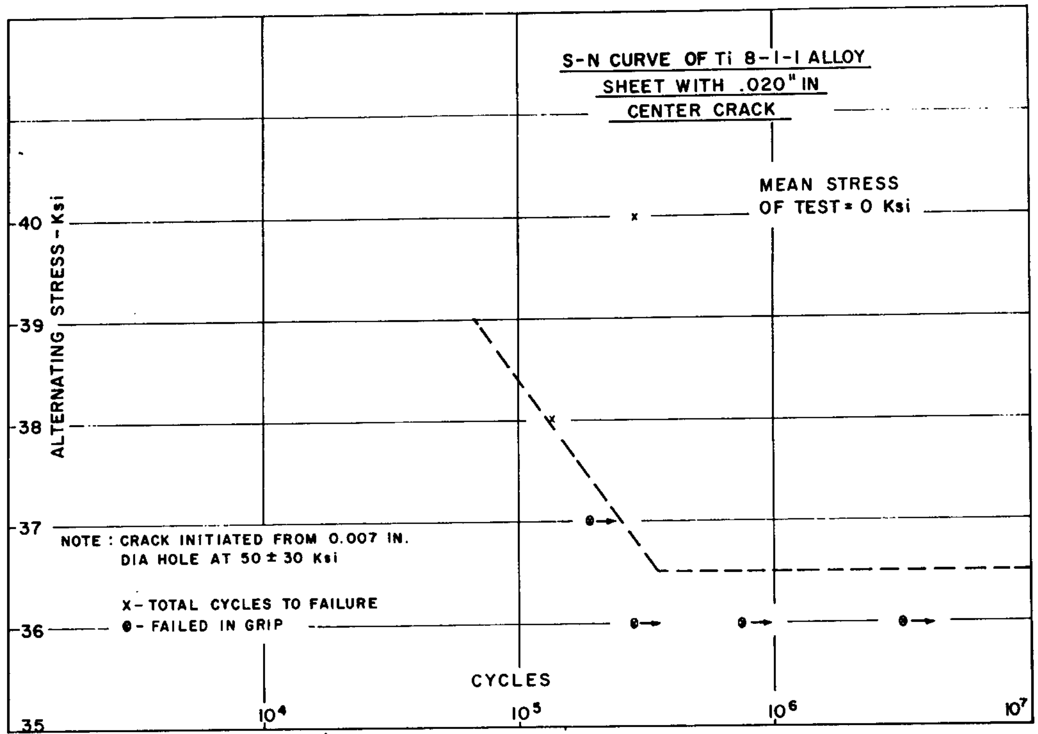

Figure 8. S-N Curve of Ti 8-1-1 alloy sheet with 0.020 in. center crack, 0 ksi mean stress.

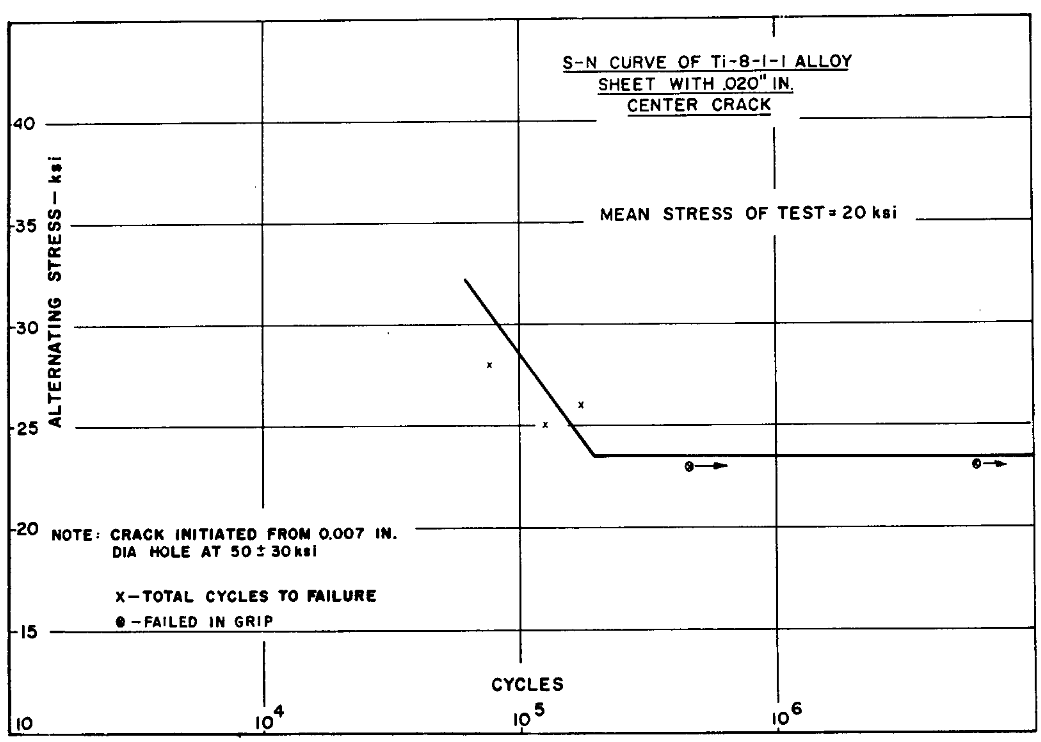

Figure 9. S-N Curve of Ti 8-1-1 alloy sheet with 0.020 in. center crack, 20 ksi mean stress.

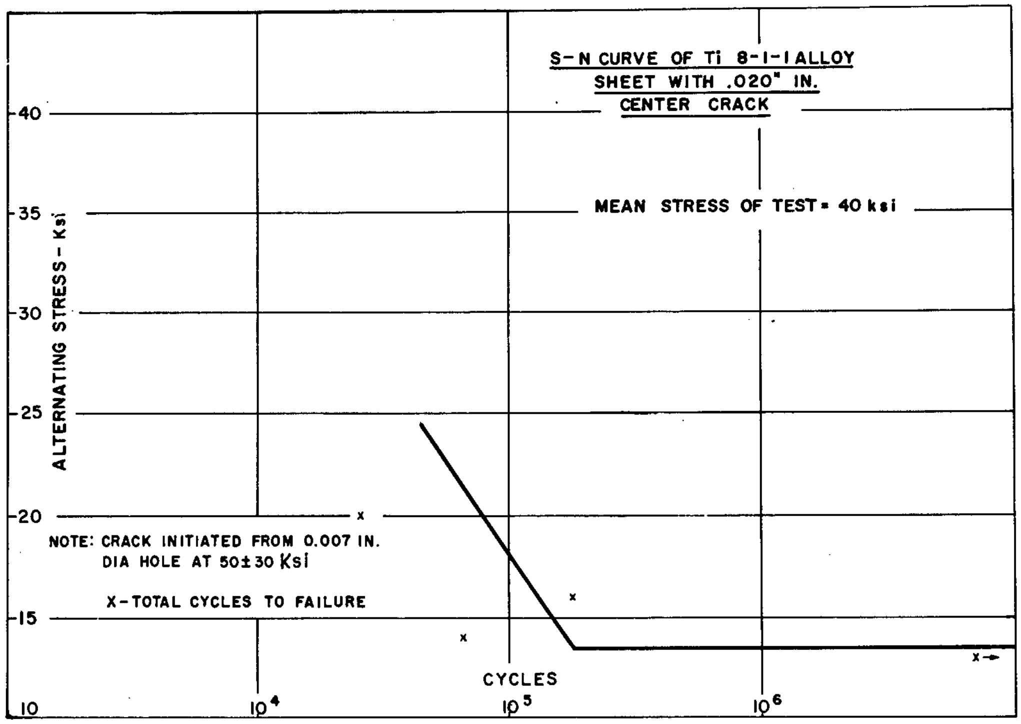

Figure 10. S-N Curve of Ti 8-1-1 alloy sheet with 0.020 in. center crack, 40 ksi mean stress.

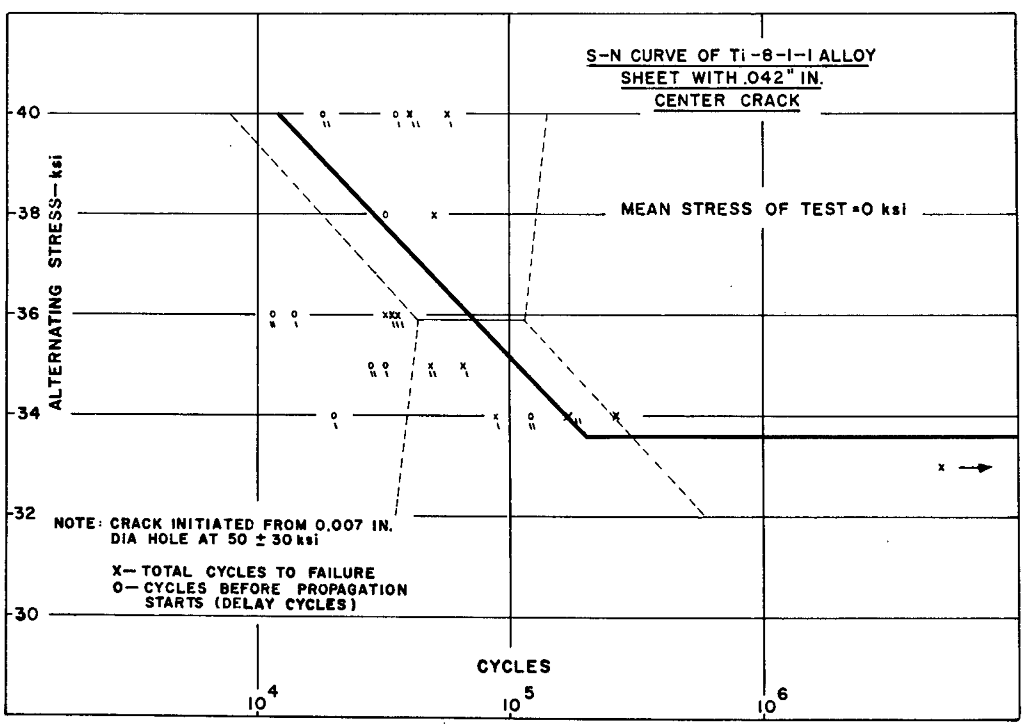

Figure 11. S-N Curve of Ti 8-1-1 alloy sheet with 0.042 in. center crack, 0 ksi mean stress.

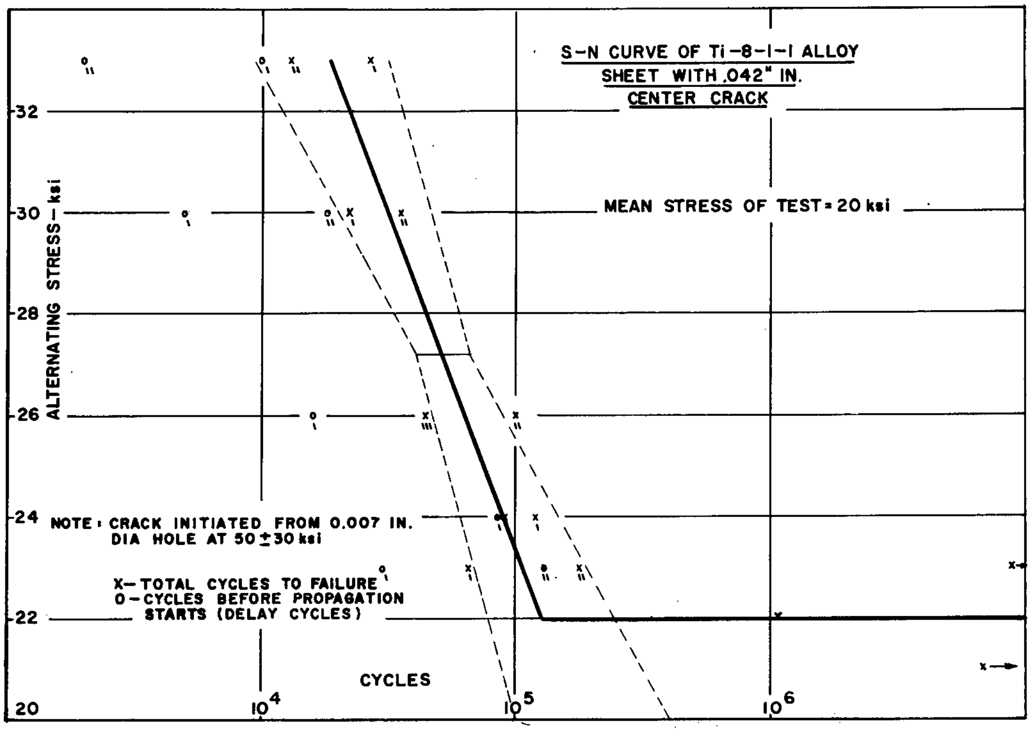

Figure 12. S-N Curve of Ti 8-1-1 alloy sheet with 0.042 in. center crack, 20 ksi mean stress.

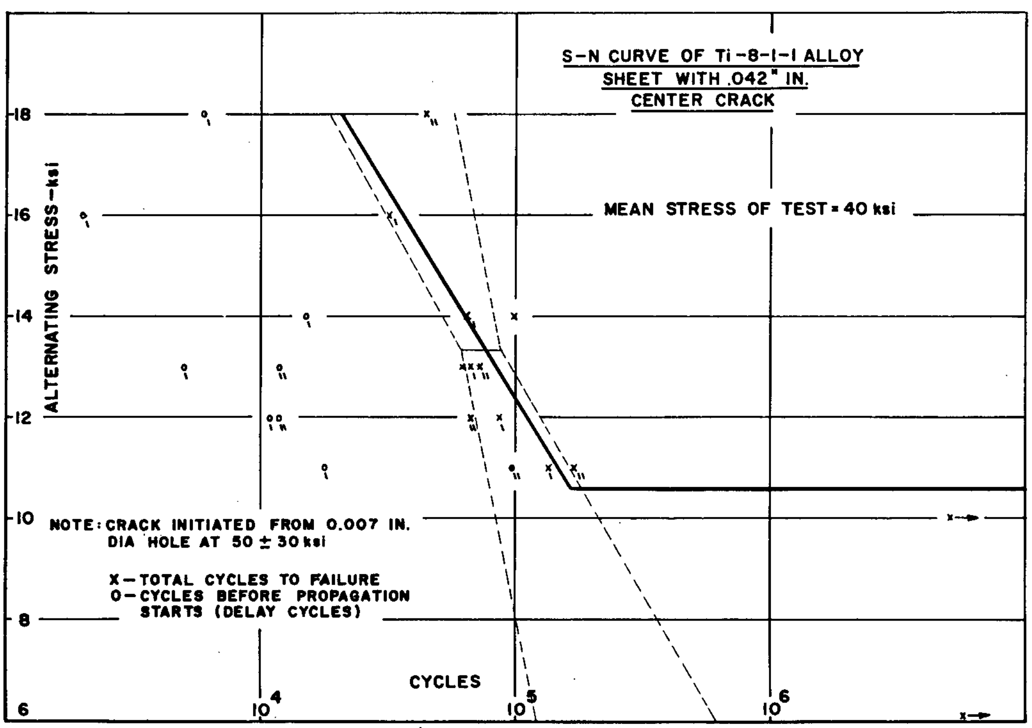

Figure 13. S-N Curve of Ti 8-1-1 alloy sheet with 0.042 in. center crack, 40 ksi mean stress.

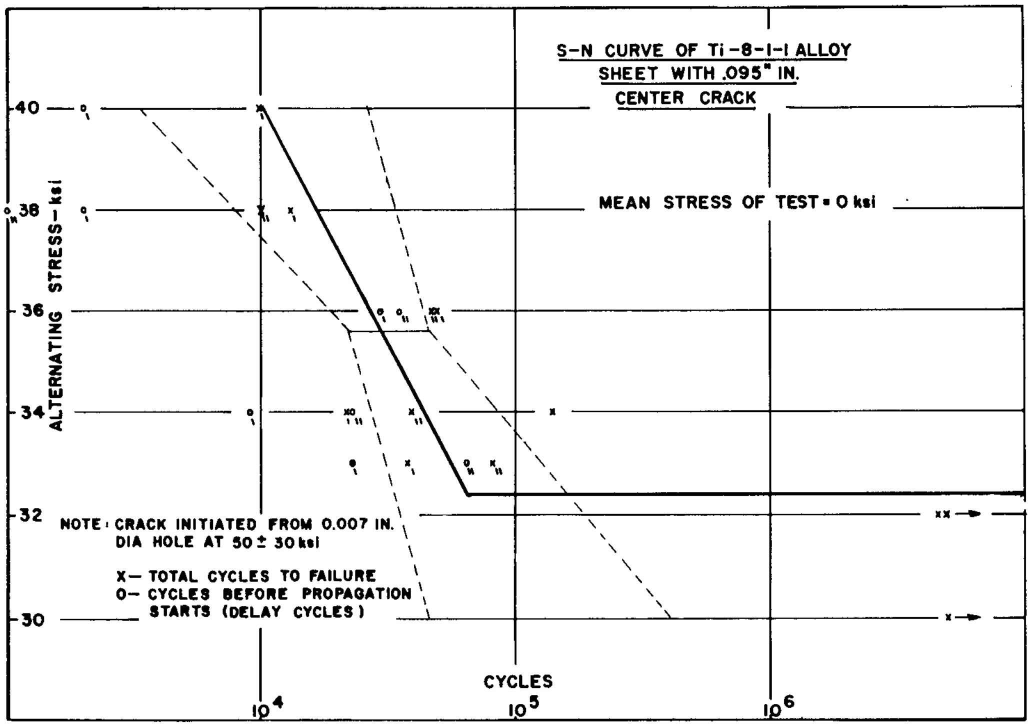

Figure 14. S-N Curve of Ti 8-1-1 alloy sheet with 0.095 in. center crack, 0 ksi mean stress.

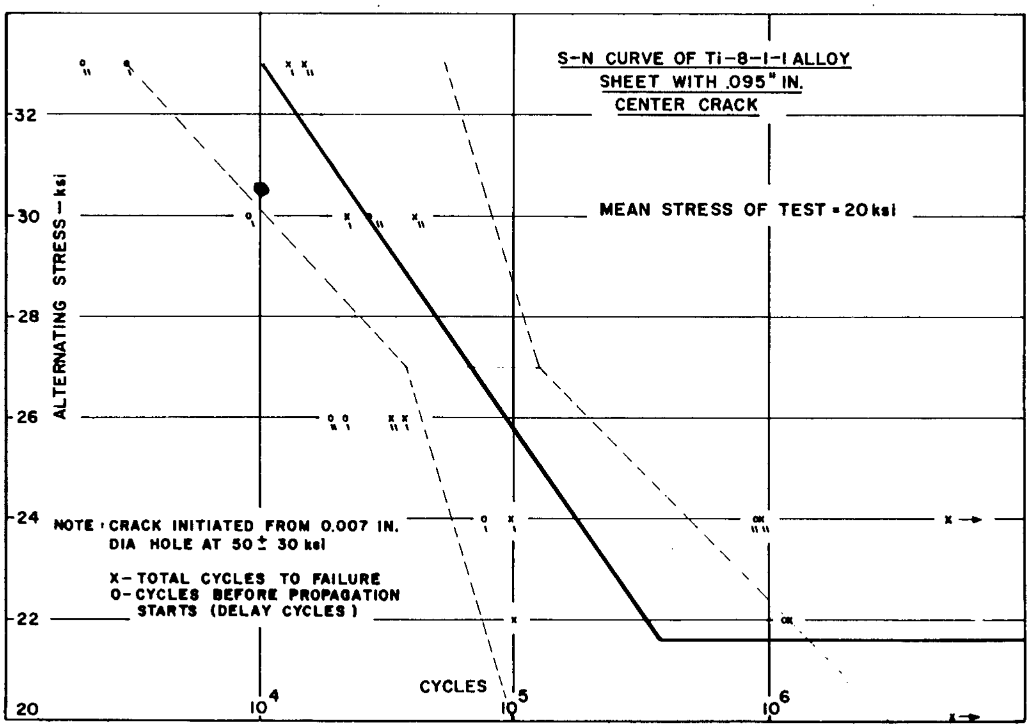

Figure 15. S-N Curve of Ti 8-1-1 alloy sheet with 0.095 in. center crack, 20 ksi mean stress.

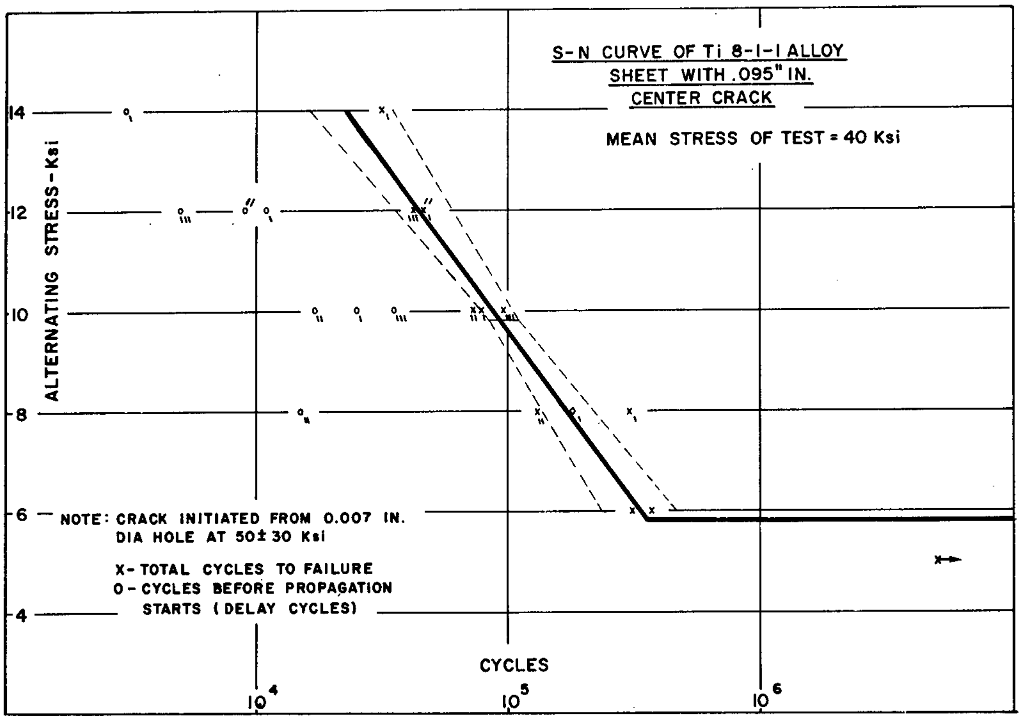

Figure 16. S-N Curve of Ti 8-1-1 alloy sheet with 0.095 in. center crack, 40 ksi mean stress.

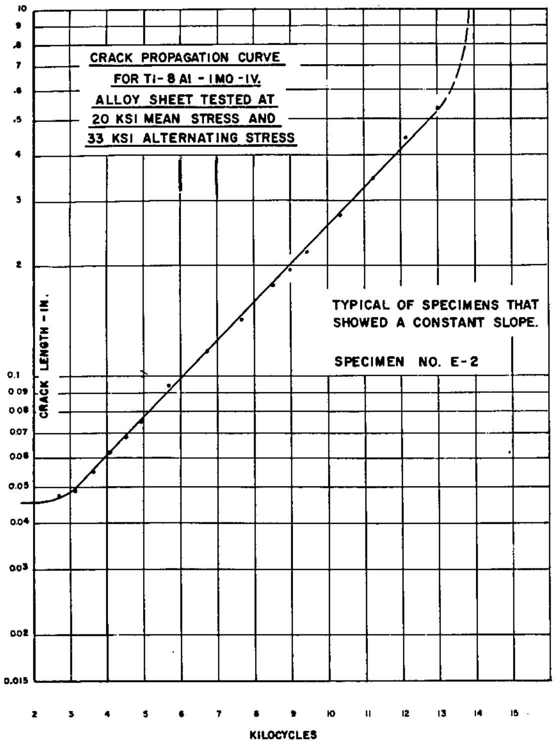

Figure 17. Crack propagation curve for Ti 8-1-1 alloy sheet tested at 20 ksi mean stress and 33 ksi alternating stress. Typical of specimens that showed a constant slope.

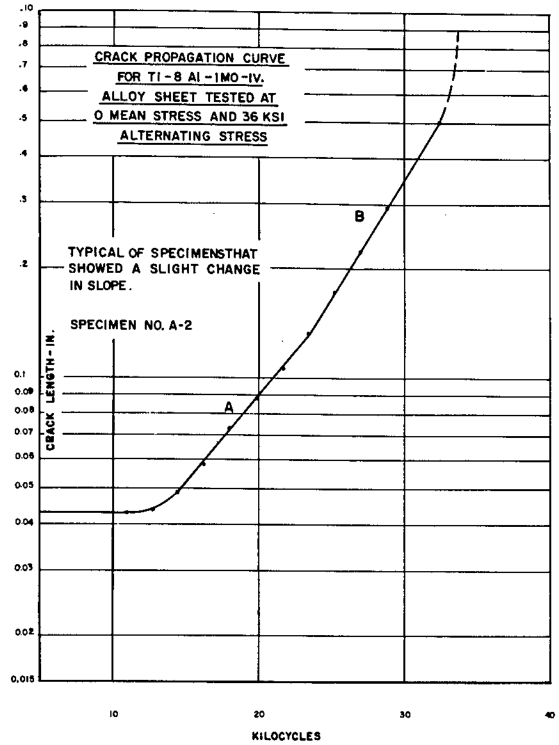

Figure 18. Crack propagation curve for Ti 8-1-1 alloy sheet tested at 0 ksi mean stress and 36 ksi alternating stress. Typical of specimens that showed a slight change in slope.

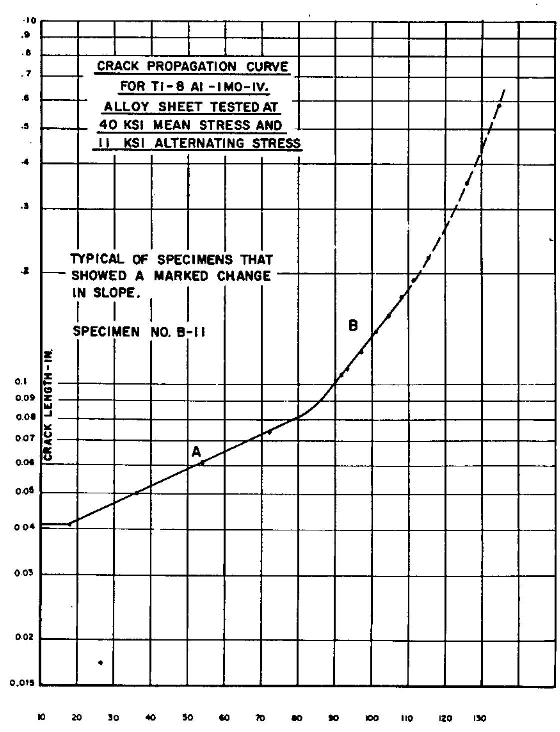

Figure 19. Crack propagation curve for Ti 8-1-1 alloy sheet tested at 40 ksi mean stress and 11 ksi alternating stress. Typical of specimens that showed a marked change in slope.

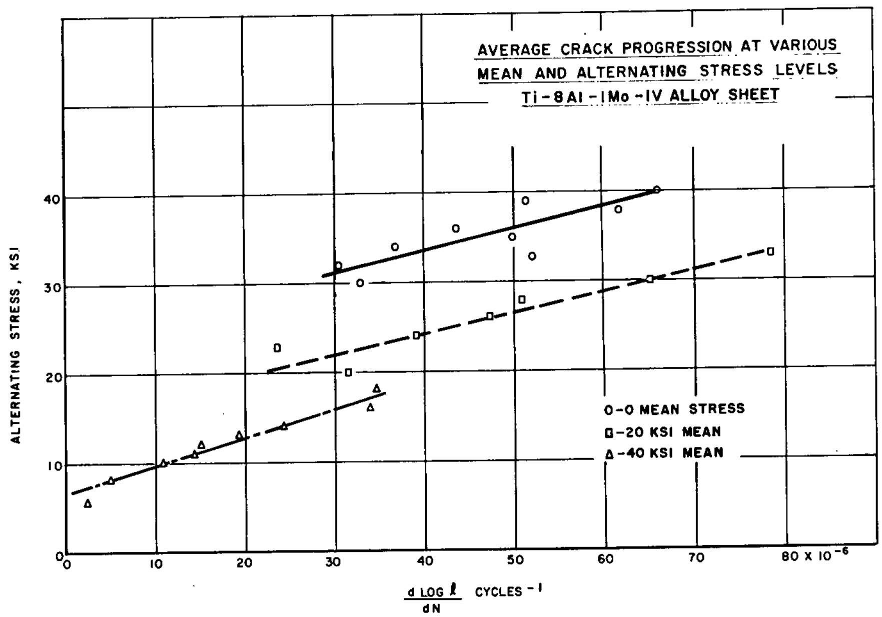

Figure 20. Average crack progression at various mean and alternating stress levels. Ti 8-1-1 alloy sheet.

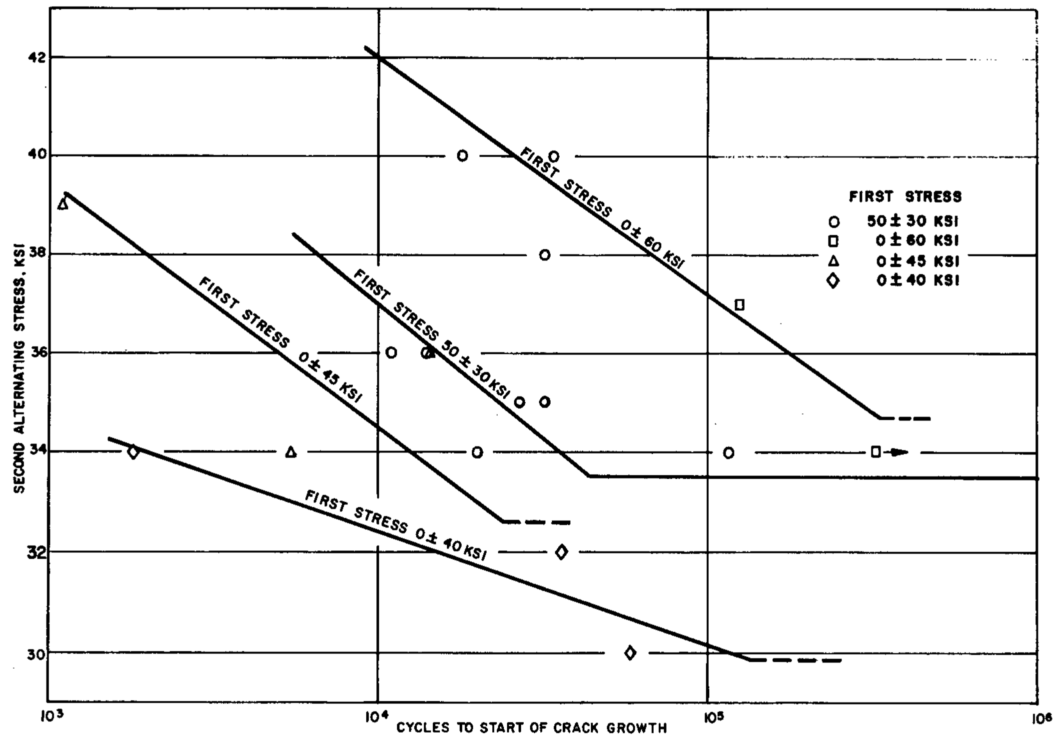

Figure 21. Delay cycles for specimens with nominal starting crack length of 0.042 in. tested at 0 ksi mean stress.

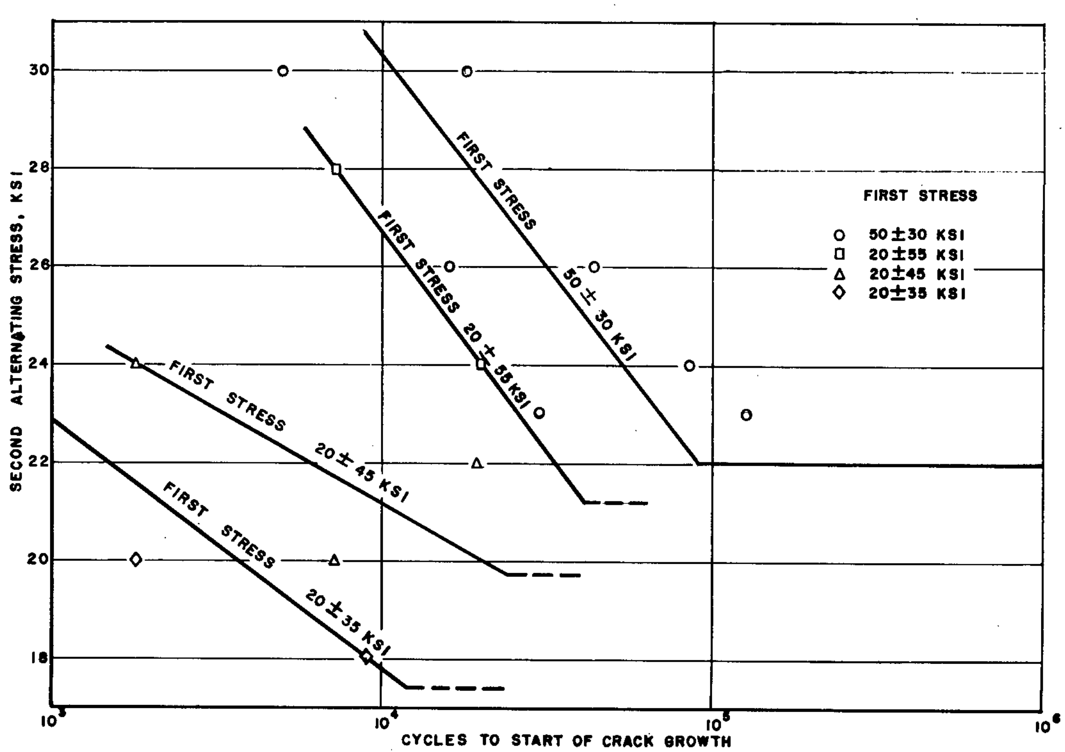

Figure 22. Delay cycles for specimens with nominal starting crack length of 0.042 in. tested at 20 ksi mean stress.

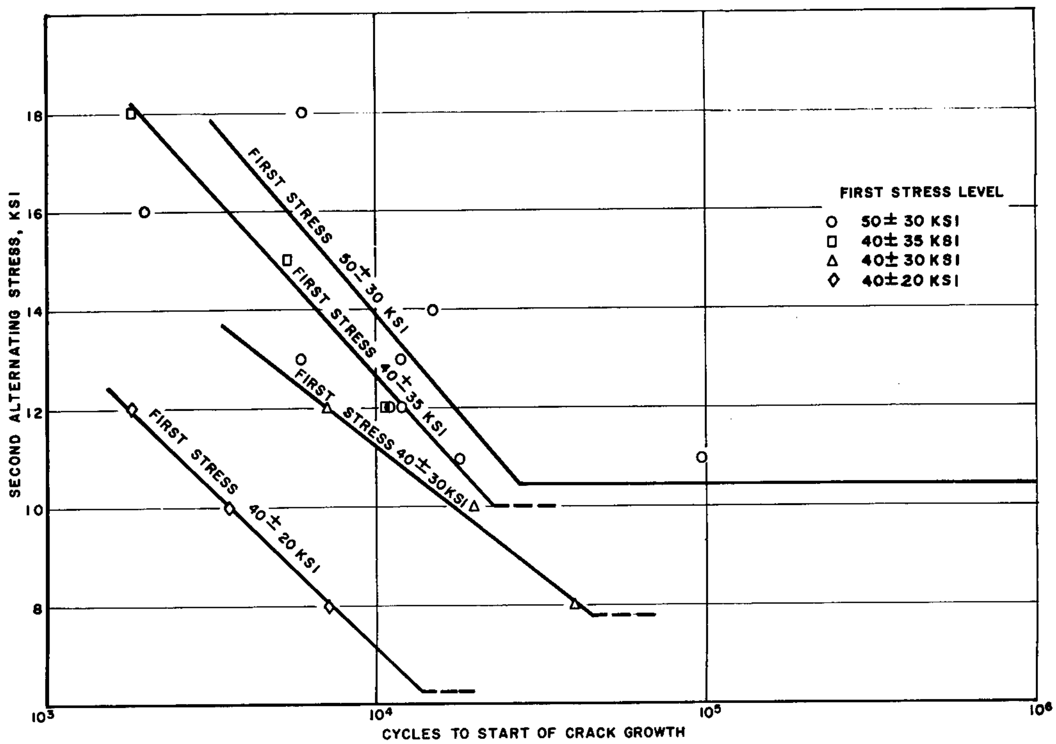

Figure 23. Delay cycles for specimens with nominal starting crack length of 0.042 in. tested at 40 ksi mean stress.

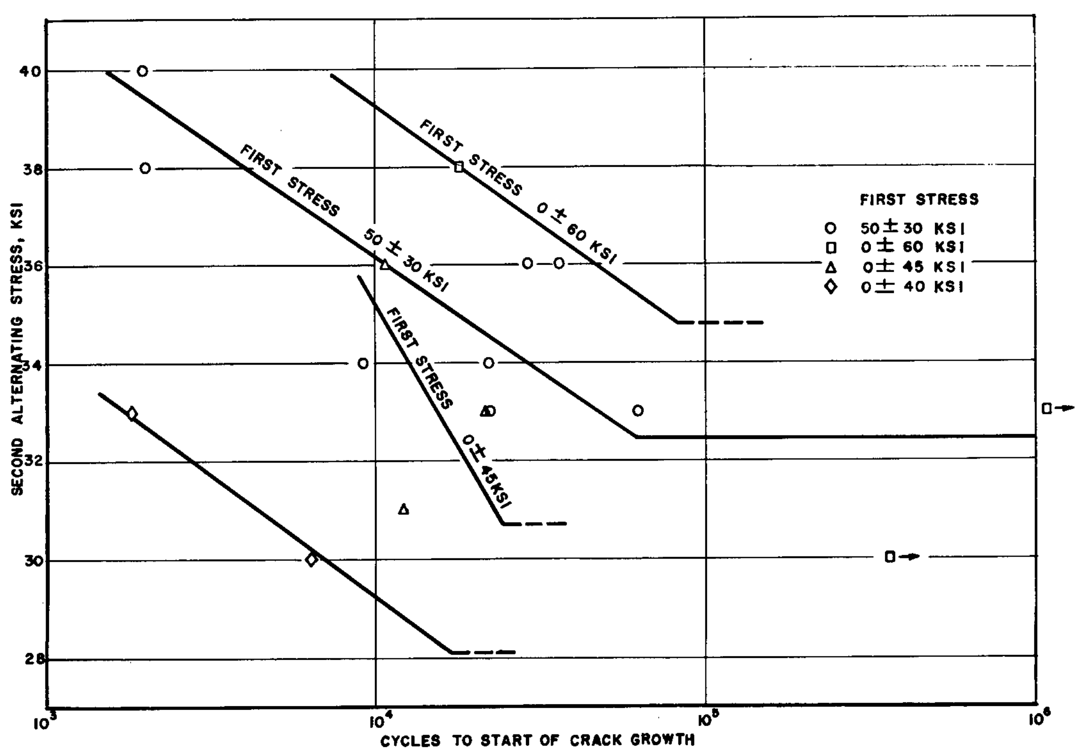

Figure 24. Delay cycles for specimens with nominal starting crack length of 0.095 in. tested at 0 ksi mean stress.

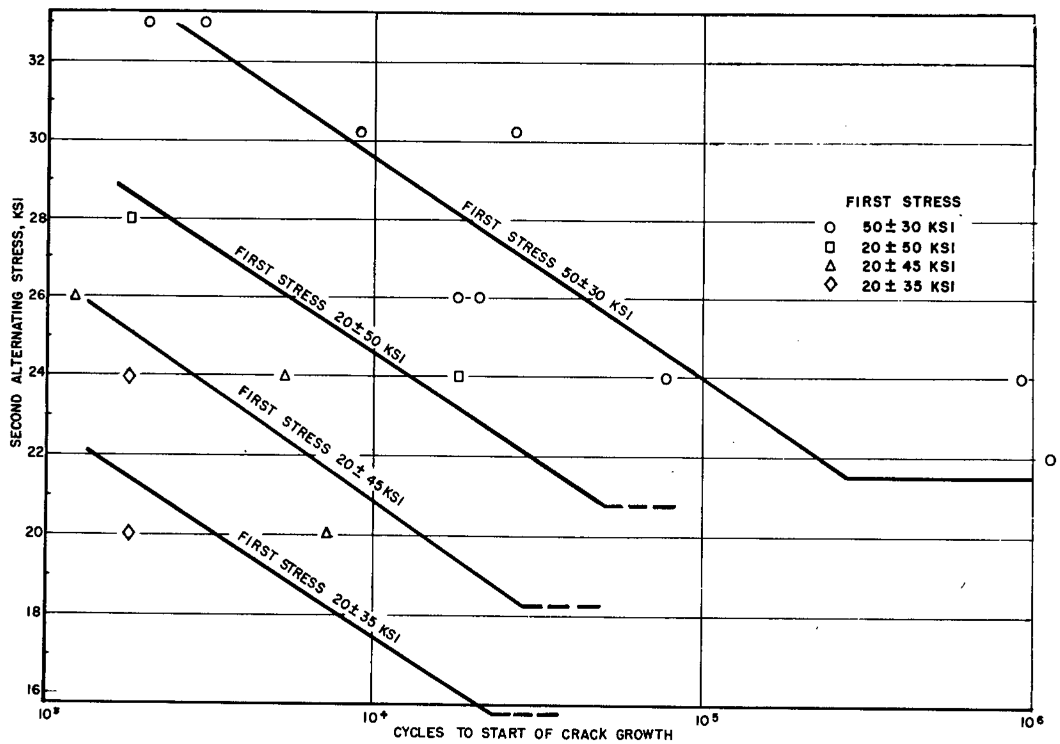

Figure 25. Delay cycles for specimens with nominal starting crack length of 0.095 in. tested at 20 ksi mean stress.

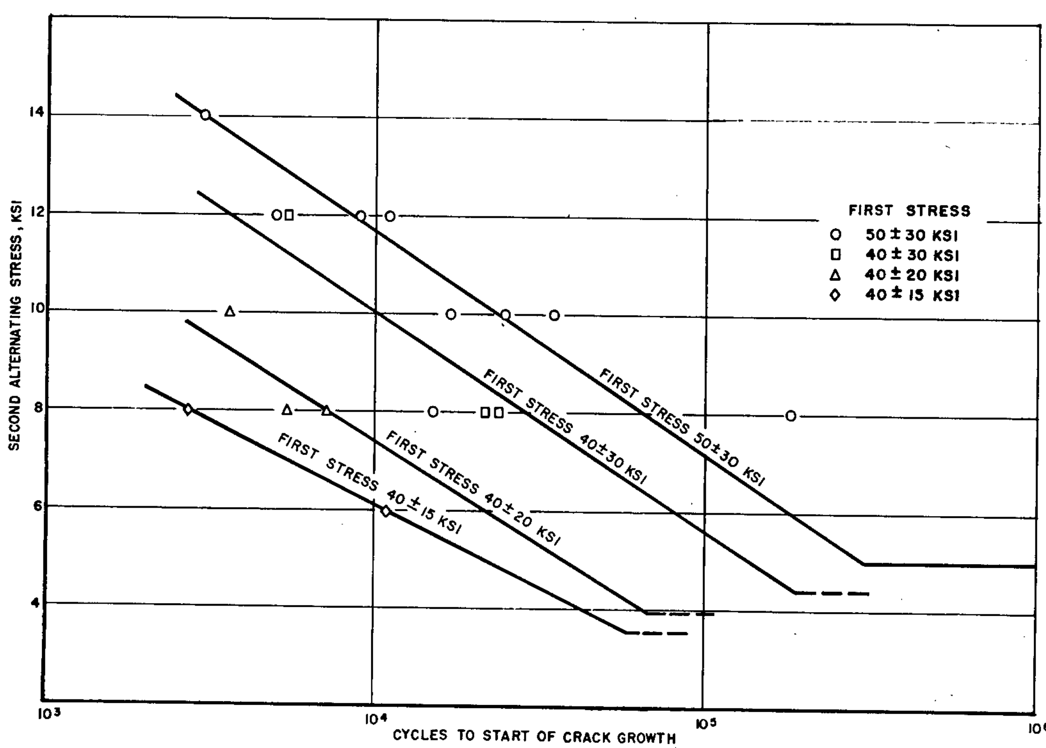

Figure 26. Delay cycles for specimens with nominal starting crack length of 0.095 in. tested at 40 ksi mean stress.

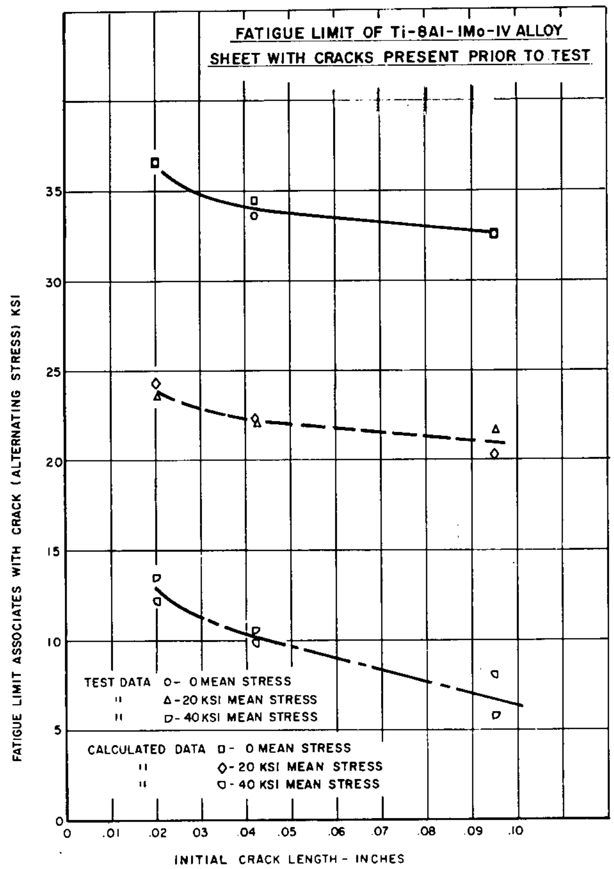

Figure 27. **Fatigue limit of Ti-8Al-1Mo-1V alloy sheet with cracks present prior to test.**

Evaluator's note:
Tables in this report contain pertinent data associated with test program.
Tables very complete.

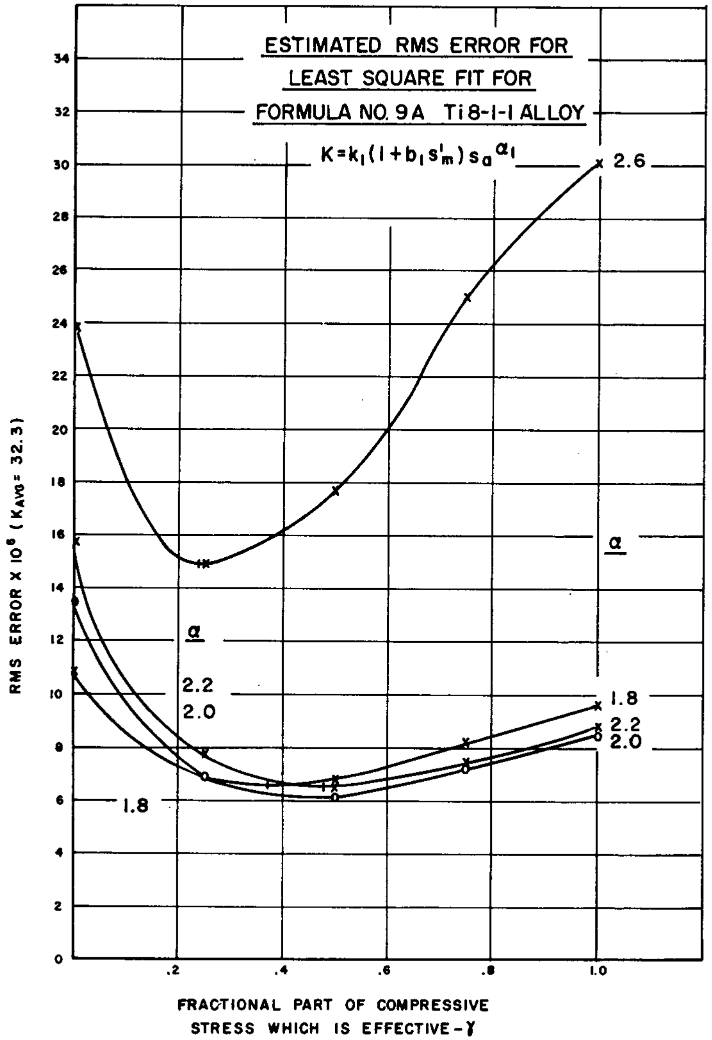

Figure 28. Estimated RMS error for least square fit for formula No. 9a Ti 8-1-1 alloy.

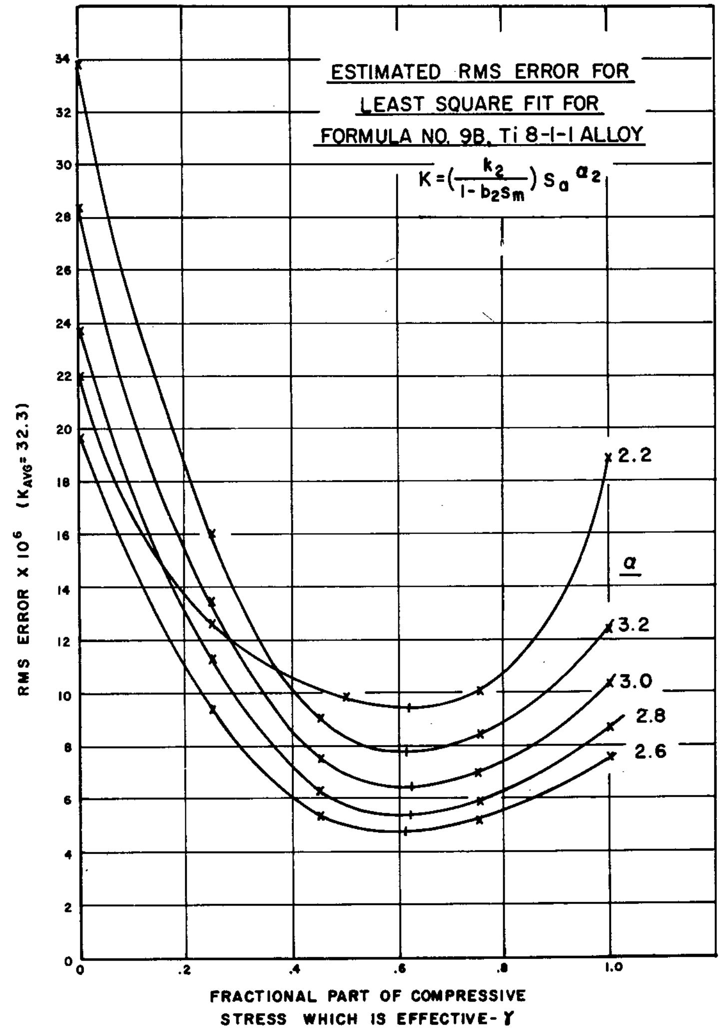

Figure 29. Estimated RMS error for least square fit for formula No. 9b Ti 8-1-1 alloy.

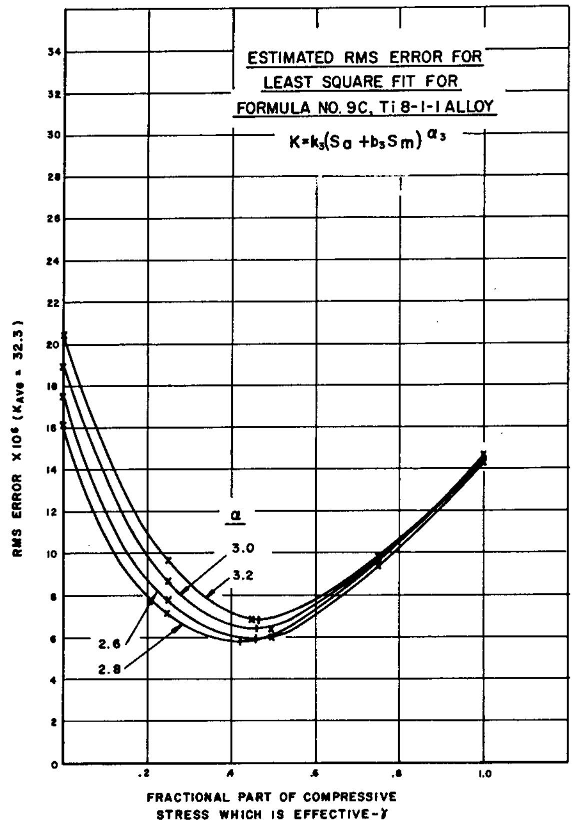

Figure 30. Estimated RMS error for least square fit for formula No. 9c Ti 8-1-1 alloy.

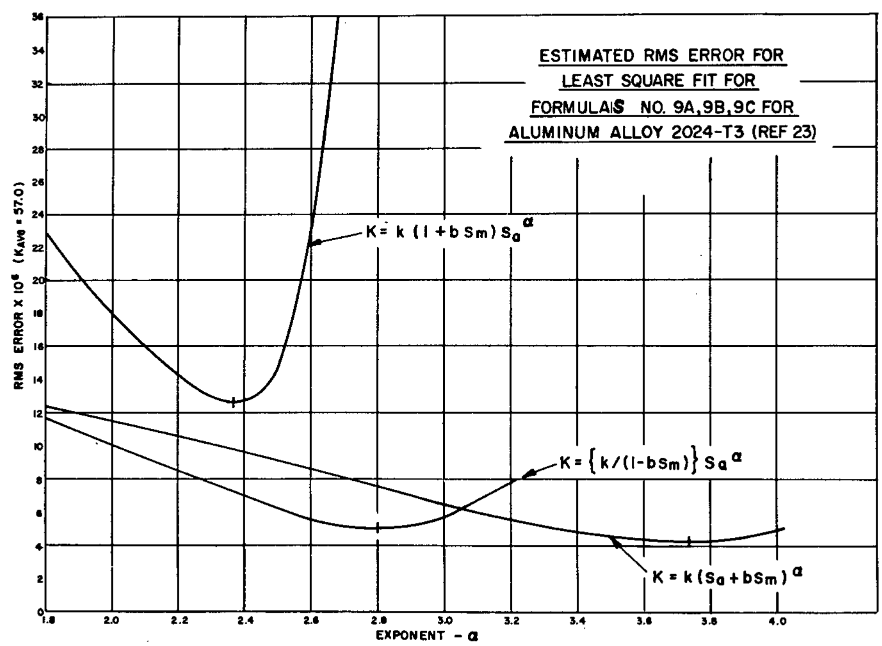

Figure 31. Estimated RMS error for least square fit for formulas No. 9a, 9b, 9c for aluminum alloy 2024-T3 (Ref. 21).

TABLE I

STRESS LEVELS AND CYCLES REQUIRED FOR GENERATION OF CRACKS OF SPECIFIC LENGTH USED FOR SUBSEQUENT TESTING IN PHASE I AND PHASE II

Nominal Crack Length	Specimen	Area Inches^2	Approx. Cycles @ 65±50 Ksi	Approx. Cycles @ 60±40 Ksi	Crack Length Inches	Approx. Cycles @ 50±30 Ksi	Final Crack Length, Inches		Remarks
							Front	Back	
0.020	A-13	0.041		14,000	0.0123	12,000	0.0198	0.0215	
	B-13	0.042		13,000	0.0128	8,000	0.0193	0.0195	
	D-7	0.044	14,000		0.0107	22,000	0.0187	-	
	F-4	0.042	12,000		0.0160	6,000	0.0224	0.0251	
	F-12	0.042		15,000	0.0133	11,000	0.0203	-	
	I-4	0.043		13,000	0.0118	12,000	0.0219	0.0198	
	I-9	0.043	11,000		0.0096	8,500	0.0209	0.0321	
	J-6	0.043	15,000		0.0139	11,000	0.0230	0.0230	
	K-2	0.043	17,000		0.0096	7,000	0.0203	-	
	M-1	0.040	19,000		0.0091	20,000	0.0161	-	
	M-5	0.043		14,000	0.0123	11,000	0.0193	0.0210	
	M-6	0.044		14,000	0.0134	9,000	0.0198	0.0190	
	M-10	0.043	11,000		0.0107	9,000	0.0219	0.0299	
	N-11	0.043		18,000	0.0118	11,000	0.0193	0.0226	
	N-14	0.041		9,000	0.0080	25,000	0.0214	0.0190	
0.042	A-2	0.040	12,000		0.0080	34,000	0.0428	0.0284	
	A-5	0.043	9,000		0.0086	19,000	0.0422	0.0374	
	A-6	0.044		15,000	0.0177	16,000	0.0460	-	
	B-7	0.044		14,000	0.0160	21,000	0.0433	0.0353	
	B-8	0.043	13,000		0.0165	18,000	0.0417	-	
	B-11	0.043		16,000	0.0182	22,000	0.0406	-	
	C-6	0.043		12,000	0.0134	11,000	0.0406	0.0321	0.010" Hole
	C-7	0.044		9,000	0.0192	8,000	0.0401	0.0314	0.010" Hole
	C-10	0.043	11,000		0.0176	12,000	0.0428	-	
	C-12	0.042	23,000		0.0182	31,000	0.0417	-	
	D-12	0.042	15,000		0.0171	8,000	0.0449	0.0492	
	E-1	0.039	27,000		0.0155	7,000	0.0412	-	
	E-2	0.041	13,000		0.0123	9,500	0.0455	0.0535	
	E-10	0.043	14,000		0.0118	9,000	0.0278	0.0422	
	E-14	0.041		14,000	0.0118	23,000	0.0321	0.0439	
	F-1	0.043	11,000		0.0106	23,000	0.0412		
	F-5	0.044				9,000*	0.0353		Eloxed hole run only @ 50±30 Ksi
	F-12B	0.042		See F-12 Above		24,000*	0.0423	0.0385	* Includes 11,000 cycles as F-12
	G-12	0.042	9,000		0.0246	7,000	0.0423	-	
	G-4	0.043	11,000		0.0123	15,000	0.0417	0.0391	
	G-7	0.044		7,000	0.0160	15,000	0.0412	0.0385	0.010" Hole
	G-9	0.044		12,000	0.0214	11,000	0.0396	0.0401	0.010" Hole
	G-10	0.043		4,000	0.0193	18,000	0.0428	-	
	H-3	0.043	12,000		0.0214	6,000	0.0439	0.0465	
	H-9	0.044		13,000	0.0161	23,000	0.0423	0.0305	
	I-1	0.039		17,000	0.0240	10,000	0.0428	-	
	I-7	0.044	12,000		0.0134	12,000	0.0417	0.0294	
	I-8	0.043		12,000	0.0123	25,000	0.0401	-	
	J-1	0.042		12,000	0.0155	19,000	0.0444	0.0359	
	J-2	0.043		12,000	0.0214	12,000	0.0417	-	
	J-9	0.043		17,000	0.0198	13,000	0.0423	-	
	J-10	0.043	13,000		0.0187	15,000	0.0433	-	
	K-5	0.043	10,000		0.0262	14,000	0.0423	-	
	K-11	0.042	12,000		0.0118	15,000	0.0421	0.0428	
	L-6	0.044	9,000		0.0225	10,000	0.0433		
	L-14	0.042	15,000		0.0182	16,000	0.0412	-	
	M-9	0.044	13,000		0.0171	12,500	0.0423	0.0433	
	N-2A	0.043	11,000		0.0160	14,000	0.0423		
	N-9	0.043		17,000	0.0176	13,000	0.0428	-	

TABLE I - Continued

STRESS LEVELS AND CYCLES REQUIRED FOR GENERATION OF CRACKS OF SPECIFIC LENGTH USED FOR SUBSEQUENT TESTING IN PHASE I AND PHASE II

Nominal Crack Length	Specimen	Area Inches^2	Approx. Cycles @ 65±50 Ksi	Approx. Cycles @ 60±40 Ksi	Crack Length Inches	Approx. Cycles @ 50±30 Ksi	Final Length, Crack Inches Front	Back	Remarks
0.095	A-1	0.041	11,000		0.0107	27,000	0.0947	0.0754	
	A-11	0.043	14,000		0.0470	7,000	0.0947	0.1017	
	A-12	0.043				30,500*	0.0947		*Eloxed hole run only at 50±30
	A-14	0.042	11,000		0.0385	6,000	0.0979	0.1054	
	B-2	0.042		15,000	0.0134	22,500	0.0845	0.1017	
	C-1	0.044				28,000*	0.0915		*Eloxed hole run only at 50±30
	C-2	0.042	10,000		0.0150	10,000	0.0952		
	C-3	0.042	12,000		0.0321	15,000	0.1043		
	D-6	0.044	12,000		0.0166	18,000	0.0903		
	D-11	0.043	11,000		0.0177	16,500	0.0984	0.0866	
	D-13	0.041	17,000		0.0118	10,000	0.0807	0.0925	
	E-6	0.043	12,000		0.0358	8,000	0.1022	0.0894	
	E-8	0.044		12,000	0.0182	18,000	0.0958	0.0717	
	E-11	0.041				29,000*	0.0963		*Eloxed hole run only at 50±30
	F-2	0.043	9,000		0.0144	23,500	0.1081	0.0824	
	F-10	0.043	15,000		0.0299	7,000	0.0942	0.0984	
	G-2B	0.042	See G-2 Above			13,000**	0.0973		**Includes 7000 cycles as G-2
	G-3	0.042		17,000	0.0123	18,500	0.0947	0.1086	
	G-5	0.043	15,000		0.0261	7,000	0.0909	0.0866	
	G-13	0.043				17,000†	0.0952		†Eloxed hole run only at 50±30
	G-14	0.041	4,000		0.0385	9,000	0.0915		
	H-2	0.042	21,000		0.0347	6,000	0.0920	0.0936	0.010" Hole
	H-4	0.043		15,000	0.0443	3,500	0.0942	0.0936	0.010" Hole
	H-6	0.044	13,000		0.0417	5,000	0.0930	0.0898	
	I-6	0.043				31,000†	0.0923		†Eloxed hole run only at 50±30
	I-11	0.0435	9,000		0.0160	14,000	0.0936		
	I-13	0.042	18,000		0.0592	3,000	0.0995	0.1091	
	J-3	0.043				21,500†	0.0918		†Eloxed Hole run only at 50±30
	J-4	0.043		13,000	0.0128	27,500	0.0979	0.0696	
	K-3	0.042	11,000		0.0139	12,000	0.0958	0.0920	
	K-4	0.043	9,000		0.0176	13,500	0.0952	0.0920	
	K-5B	0.043	See K-5 Above			20,000ϕ	0.0942		ϕIncludes 14,000 cycles as K-5
	K-9	0.042				24,000†			†Eloxed Hole run only at 50±30
	K-13	0.042		5,000	0.0279	15,000	0.0958		
	L-1	0.042				29,000†	0.1091		†Eloxed Hole run only at 50±30
	L-7	0.0435	10,000		0.0155	20,000	0.0910		
	L-10	0.043	9,000		0.0112	18,000	0.0947		
	L-11	0.043	24,000		0.0214	5,000	0.0931	-	
	L-12	0.042		23,000	0.0214	6,000	0.0931	-	
	L-13	0.042		18,000	0.0107	22,000	0.1006	0.1204	
	M-4	0.042	11,000		0.0182	8,000	0.0952	0.0819	
	M-14	0.041	13,000		0.0112	20,000	0.0925		
	N-2	0.042	15,000		0.0225	12,000	0.1043		
	N-2AB **	0.043	See N-2A Above			17,000*	0.0952		*Includes 14,000 cycles as N-2A
	N-7	0.043	12,000		0.0428	5,500	0.1022	0.1139	

** Vendor marked two specimens as N-2. One was arbitrarily called N-2A.

TABLE II

FATIGUE DATA FOR SPECIMENS WITH SPECIFIC CRACK LENGTHS TESTED BY STEP TEST METHOD
Ti 8 Al - 1 Mo - 1 V Alloy Sheet Tested At Various Mean Stresses

Specimen Number	Starting Crack Length Inches	Mean Stress Ksi	Alternating Stress Ksi			No. Of Alternating Stress Steps	Remarks
			Start	Stress Increment Between Steps	Final		
F-5	0.0353	0	±15	3	±33	7*	Failed after 163,000 cycles at ±33 ksi
C-1	0.0915	0	±18	2	±32	8**	Failed after 938,000 cycles at ±32 ksi
K-9	0.0928	0	±24	2	±32	5**	Grip failed after 1,220,000 cycles at ±32 ksi
J-3	0.0918	0	±26	2	±36	6**	Grip failed after 3,254,000 cycles at ±36 ksi
L-7	0.0910	0	±30	2	±34	3*	Failed after 20,000 cycles at 34 ksi
G-2	0.0952	0	±32	2	±36	3*	Failed after 80,000 cycles at ±36 ksi
L-1	0.1091	20	±14	2	±26	7*	Failed after 187,000 cycles at ±26 ksi
G-14	0.0915	20	±18	2	±26	5*	Failed after 70,000 cycles at ±26 ksi
I-11	0.0936	20	±20	2	±24	3*	Failed after 2,969,000 cycles at ±24 ksi
M-14	0.0925	20	±22	-	±22	1	Failed after 99,000 cycles at ±22 ksi
G-13	0.0925	40	±2	1	±6	5**	Failed after 8,284,000 cycles at ±6 ksi due to tensile overload
K-13	0.0958	40	±5	1	±13	9*	Failed after 112,000 cycles at 13 ksi
A-12	0.0947	40	±6	-	±6	1	Failed after 316,000 cycles at ±6 ksi
L-10	0.0947	40	±6	-	±6	1	Failed after 381,000 cycles at ±6 ksi
E-11	0.0963	50	±12	-	±12	1	Failed after 36,000 cycles at ±12 ksi
I-6	0.0926	50	±18	-	±18	1	Failed after 16,000 cycles at ±18 ksi

* 5×10^6 cycles before raising to higher stress level.

** 10×10^6 cycles before raising to higher stress level.

TABLE III

FATIGUE DATA FOR SPECIMENS WITH SPECIFIC CRACK LENGTHS, TESTS CONDUCTED BY CONVENTIONAL METHODS
Ti 8 Al - 1 Mo - 1 V Alloy Sheet Tested At Various Mean and Alternating Stresses

Nominal Crack Size, In.	Actual Crack Size Front In.	Actual Crack Size Back In.	Specimen	Gross Mean Stress Ksi	Gross Alternating Stress Ksi	Kilocycles To Start Of Crack Growth	Kilocycles To Failure	Remarks
0.020	0.0193	0.0226	N-11	0	±36	-	3,170	Broke in Grip-No Growth
	0.0198	0.0215	A-13	0	±36		280	"
	0.0209	0.0321	I-9	0	±36		740	"
	0.0193	0.0195	B-13	0	±37		190	"
	0.0214	0.0190	N-14	0	±38		132	
	0.0219	0.0198	I-4	0	±40		279	
	0.0193	0.0210	M-5	20	±23		6,021	Broke in Grip-No Growth
	0.0198	0.0190	M-6	20	±23		462	"
	0.0230	0.0230	J-6	20	±25		127	
	0.0224	0.0251	F-4	20	±26		176	
	0.0219	0.0299	M-10	20	±28		77	
	0.0203	-	F-12	40	±13		7,220	Did not fail
	0.0187	-	D-7	40	±14		65	
	0.0161	-	M-1	40	±16		182	
	0.0203	-	K-2	40	±20		26	
0.042	0.0433	-	L-6	0	±33	-	5,061	Did not fail
	0.0417	-	B-8	0	±34		263	
	0.0417	0.0391	G-4	0	±34	20	87	
	0.0417	0.0294	I-7	0	±34	117	170	
	0.0444	0.0359	J-1	0	±35	32	65	
	0.0449	0.0492	D-12	0	±35	27	48	
	0.0321	0.0439	E-14	0	±36	14	35	
	0.0428	0.0284	A-2	0	±36	11	34	
	0.0428	-	C-10	0	±36	-	32	
	0.0278	0.0422	E-10	0	±38	32	50	
	0.0439	0.0465	H-3	0	±40	34	56	
	0.0423	0.0305	H-9	0	±40	18	40	
	0.0412	-	E-1	20	±21	-	6,829	Did not fail
	0.0412	-	L-14	20	±22	-	1,076	
	0.0421	0.0428	K-11	20	±23	-	8,943	Did not fail
	0.0406	0.0321	C-6	20	±23	30	65	
	0.0433	0.0353	B-7	20	±23	126	177	
	0.0433	-	J-10	20	±24	-	89	
	0.0423	0.0433	M-9	20	±24	85	120	
	0.0401	0.0314	C-7	20	±26	16	44	
	0.0428	-	G-10	20	±26	44	101	
	0.0423	0.0385	F-12B	20	±30	5	22	
	0.0422	0.0374	A-5	20	±30	18	35	
	0.0421	0.0428	K-11B	20	±33	10	27	
	0.0455	0.0535	E-2	20	±33	2	13	
	0.0423	-	K-5	40	±6	-	5,619	Did not fail
	0.0423	-	G-2	40	±10	-	5,121	Did not fail
	0.0417	-	J-2	40	±11	97	169	
	0.0406	-	B-11	40	±11	18	137	
	0.0412	0.0385	G-7	40	±12	11	87	
	0.0460	-	A-6	40	±12	12	66	
	0.0417	-	C-12	40	±13	-	62	
	0.0396	0.0401	G-9	40	±13	5	66	
	0.0401	-	I-8	40	±13	12	72	
	0.0412	-	F-1	40	±14	-	101	
	0.0423	-	J-9	40	±14	15	64	
	0.0428	-	N-9	40	±16	2	32	
	0.0428	-	I-1	40	±18	6	45	

(Continued)

TABLE III - Continued

FATIGUE DATA FOR SPECIMENS WITH SPECIFIC CRACK LENGTHS, TESTS CONDUCTED BY CONVENTIONAL METHODS
Ti 8 Al - 1 Mo - 1 V Alloy Sheet Tested At Various Mean and Alternating Stresses

Nominal Crack Size, In.	Actual Crack Size Front In.	Actual Crack Size Back In.	Specimen	Gross Mean Stress Ksi	Gross Alternating Stress Ksi	Kilocycles To Start Of Crack Growth	Kilocycles To Failure	Remarks
0.095	0.0918	-	J-3	0	±26	-	10,169	Did not fail
	0.0910	-	L-7	0	±30	-	5,000	Did not fail
	0.0952	-	C-2	0	±32		5,018	Did not fail
	0.0979	0.0696	J-4	0	±32		4,589	Failed at Bolt Hole
	0.0952	0.0819	M-4	0	±33	22	38	
	0.1022	0.0894	E-6	0	±33	63	82	
	0.0952	-	N-2AB	0	±34	-	139	
	0.1022	0.1139	N-7	0	±34	9	22	
	0.0807	0.0925	D-13	0	±34	22	39	
	0.0947	0.0754	A-1	0	±36	29	49	
	0.0995	0.1091	I-13	0	±36	36	47	
	0.0984	0.0866	D-11	0	±38	Negl	10	
	0.0952	0.0920	K-4	0	±38	2	13	
	0.0947	0.1017	A-11	0	±40	2	10	
	0.0915	-	G-14	20	±18	-	7,042	Did not fail
	0.0936	-	I-11	20	±20	-	5,190	Did not fail
	0.0925	-	M-14	20	±22	-	99	
	0.0909	0.0866	G-5	20	±22	1,135	1,153	
	0.0930	0.0898	H-6	20	±24	-	5,018	Did not fail
	0.0942	0.0936	H-4	20	±24	77	97	
	0.0947	0.1086	G-3	20	±24	923	941	
	0.0920	0.0936	H-2	20	±26	22	37	
	0.1006	0.1204	L-13	20	±26	18	33	
	0.0979	0.1054	A-14	20	±30	9	22	
	0.0942	0.0984	F-10	20	±30	27	41	
	0.1081	0.0824	F-2	20	±33	3	13	
	0.0958	0.0920	K-3	20	±33	2	15	
	0.0958	-	K-13	40	±5	-	5,005	Did not fail
	0.0947	-	A-12	40	±6	-	316	
	0.0947		L-10	40	±6	-	381	
	0.0903	-	D-6	40	±8	182	304	
	0.0845	0.1017	B-2	40	±8	15	130	
	0.0931	-	L-12	40	±10	25	80	
	0.1043	-	C-3	40	±10	17	74	
	0.0931	-	L-11	40	±10	35	96	
	0.1043	-	N-2	40	±12	11	46	
	0.0973	-	G-2B	40	±12	9	46	
	0.0942		K-5B	40	±12	5	44	
	0.0958	0.0717	E-8	40	±14	3	32	

TABLE IV

RATE OF CRACK PROGRESSION FOR Ti - 8 Al - 1 Mo - 1 V ALLOY SHEET
TESTED AT 0 MEAN STRESS AND VARIOUS ALTERNATING STRESSES
STARTING CRACK LENGTH - 0.042" NOMINAL

Specimen G-4
0 ± 34 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.042	
19,800	0.042	
21,600	0.044	
25,200	0.050	
28,800	0.064*	
32,400	0.078	0.00002446
36,000	0.096*	
39,600	0.114	
43,200	0.133	.00001896
46,800	0.155	
50,400	0.180*	
54,000	0.203	
57,600	0.225	
61,200	0.255	
64,800	0.271	
68,400	0.276	
72,000	0.312	
75,600	0.339	
79,200	0.364	
82,800	0.405	
86,400	0.605	
87,000	Failed	0.00002171 Average of 2 slopes .00002446 .00001896

Specimen I-7
0 ± 34 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.042	
117,000	0.042	
118,800	0.048	
120,600	0.051	
122,400	0.072*	
124,200	0.087	
126,000	0.101	
127,800	0.117	0.00003662
129,600	0.136	
131,400	0.160	
133,200	0.179*	
134,000	Failed In Grip	
170,000	Extrapolated Failure Value	

The values of $\frac{\Delta \log \ell}{\Delta N}$ is obtained from interval between asterisks.

Specimen J-1
0 ± 35 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.036	
32,400	0.036	
36,000	0.041	
39,600	0.043	
43,200	0.047*	
46,800	0.072	
50,400	0.101	0.00004723
54,000	0.146	
57,600	0.225*	

Specimen D-12
0 ± 35 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.045	
27,000	0.045	
28,800	0.049	
30,600	0.067	
32,400	0.086*	
34,200	0.107	
36,000	0.134	0.00005245
37,800	0.164	
39,600	0.204	
41,400	0.255*	
43,200	0.320	
45,000	0.405	
46,800	0.544	
48,000	Failed	

Specimen E-14
0 ± 36 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.044	
14,400	0.044	
16,200	0.045	
18,000	0.059*	
19,800	0.072	0.00004823
21,600	0.088*	
23,400	0.109	
25,200	0.138	0.00005689
27,000	0.178	
28,800	0.226	
30,600	0.295	
32,400	0.384	
34,200	0.519	
35,000	Failed	
		Average of 2 Slopes 0.00005156

Specimen A-2
0 ± 36 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.043	
10,800	0.043	
12,600	0.044	
14,400	0.049*	
16,200	0.058	
18,000	0.073	0.00004782
19,800	0.088	
21,600	0.107	
23,400	0.132*	
25,200	0.172	0.00006362
27,000	0.222	
28,800	0.291	
30,600	0.379*	
32,400	0.501	
34,000	Failed	Average of 2 Slopes 0.00005572

Specimen E-10
0 ± 38 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.042	
31,950	0.042	
32,400	0.046	
34,200	0.062	
35,100	0.072*	
36,000	0.082	
37,800	0.105	
39,600	0.132	0.00006133
41,400	0.171	
43,200	0.221	
45,000	0.290	
46,800	0.376*	
48,600	0.514	
50,000	Failed	

Specimen H-3
0 ± 40 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.0465	
34,650	0.0465	
35,100	0.050	
36,000	0.057*	
36,900	0.064	0.00005521
38,700	0.080	
40,500	0.101*	
42,300	0.120*	
44,100	0.144	
45,900	0.178	0.00004708
47,700	0.219	
49,500	0.268*	
51,300	0.352	
53,100	0.454	
54,900	0.647	
56,000	Failed	Average of 2 Slopes 0.00005115

Specimen H-9
0 ± 40 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.042	
18,000	0.042	
19,800	0.048	
20,700	0.051*	
21,600	0.056	
23,400	0.065	0.00004202
25,200	0.079	
26,100	0.086*	
27,000	0.096	0.00005110
28,800	0.118*	
30,600	0.150	0.00005998
32,400	0.194*	
34,200	0.251	
36,000	0.329	
37,800	0.435	
39,600	0.648	
40,000	Failed	Average of 2 Slopes 0.00005110

TABLE V

RATE OF CRACK PROGRESSION FOR Ti - 8 Al - 1 Mo - 1 V ALLOY SHEET
TESTED AT 20 KSI MEAN STRESS AND VARIOUS ALTERNATING STRESSES
STARTING CRACK LENGTH 0.042" NOMINAL

Specimen B-7
20 ± 23 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.043	
126,000	0.043	
127,800	0.044*	
129,600	0.048	
131,400	0.052	
133,200	0.055	
135,000	0.059	
136,800	0.063	0.00001656
140,400	0.072	
142,200	0.076	
149,400	0.099	
153,000	0.114	
156,600	0.132*	
160,200	0.154	
165,600	0.214	
171,000	0.257	
174,600	0.376	
176,400	0.465	
177,000	Failed	

Specimen C-6
20 ± 23 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.041	
32,400	0.042	
36,000	0.044*	
39,600	0.055	0.00002695
43,200	0.070	
46,800	0.086*	
50,400	0.120	
54,000	0.158	0.00003956
57,600	0.230*	
61,200	0.356	
64,800	0.646	
65,000	Failed	Average of
		2 Slopes
		0.00003326

Specimen M-9
20 ± 24 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.043	
81,000	0.043	
90,000	0.052	
91,800	0.056*	
97,200	0.074	0.00002012
101,800	0.089*	
102,600	0.101	
104,400	0.108	
106,200	0.139*	
108,000	0.164	0.00004015
109,800	0.193	This slope
111,600	0.229*	used
117,000	0.404	
118,800	0.513	
120,000	Failed	

Specimen G-10
20 ± 26 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.043	
40,500	0.043	
45,000	0.044	
54,000	0.052*	
63,000	0.060	0.000008053
72,000	0.072*	
81,000	0.093*	
81,900	0.100	
82,700	0.108	
85,500	0.118	0.00002997
87,300	0.135	This slope
89,100	0.156	used
90,000	0.165*	
90,900	0.180	
91,800	0.200	
94,500	0.263	
99,000	0.474	
100,350	0.628	
101,000	Failed	

Specimen C-7
20 ± 26 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.031	
18,000	0.034	
20,250	0.035	
22,500	0.040*	
24,750	0.050	0.00004297
27,000	0.064	
29,250	0.078*	
31,500	0.104	
33,750	0.135	0.00005380
36,000	0.180*	
38,250	0.243	
40,500	0.336	
42,750	0.498	
44,000	Failed	Average of
		2 Slopes
		0.00004839

Specimen F-12B
20 ± 30 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.042	
4,950	0.042	
5,400	0.045	
9,000	0.073*	
10,800	0.095	
11,700	0.110	
12,600	0.123	0.00006420
13,500	0.141	
14,400	0.162	
15,300	0.184	
15,750	0.198*	
16,200	0.214	
18,000	0.284	
21,150	0.530	
21,600	0.620	
22,000	Failed	

Specimen A-5
20 ± 30 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.042	
18,000	0.042	
20,250	0.051	
22,500	0.066*	
25,200	0.099	
26,100	0.114	0.00006563
27,000	0.132	
27,900	0.148	
28,800	0.171*	
29,700	0.200	
31,500	0.270	
34,200	0.468	
34,650	0.517	
35,000	Failed	

Specimen K-11B
20 ± 33 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.043	
9,000	0.043	
13,500	0.064*	
16,200	0.096	
17,100	0.109	
18,000	0.126	0.00006637
18,900	0.145	
19,800	0.168	
20,700	0.192	
21,150	0.206*	
22,500	0.253	
26,100	0.512	
27,000	Failed	

Specimen E-2
20 ± 33 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.045	
2,250	0.045	
4,500	0.068*	
5,850	0.094	
6,750	0.116	
7,650	0.142	0.0001043
8,550	0.176	
9,450	0.219	
10,350	0.274	
11,250	0.344*	
12,150	0.446	
13,050	0.538	
13,000+	Failed	

TABLE VI

RATE OF CRACK PROGRESSION FOR Ti - 8 Al - 1 Mo - 1 V ALLOY SHEET
TESTED AT 40 KSI MEAN STRESS AND VARIOUS ALTERNATING STRESSES
STARTING CRACK LENGTH 0.042" NOMINAL

Specimen J-2
40 ± 11 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.042	
90,000	0.042	
108,000	0.053	
126,000	0.095*	
129,600	0.109	
133,200	0.125	
136,800	0.142	0.00001604
140,400	0.162	
144,000	0.184	
147,600	0.211*	
162,000	0.390	
167,400	0.572	
169,000	Failed	

Specimen B-11
40 ± 11 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.041	
18,000	0.041*	
36,000	0.050	
54,000	0.061	0.000004749
72,000	0.074*	
90,000	0.101	
91,800	0.105*	
93,600	0.110	
97,200	0.122	0.00001275
100,800	0.138	Slope used
104,400	0.152*	
108,000	0.172	
111,600	0.193	
115,200	0.220	
126,000	0.353	
135,000	0.583	
137,000	Failed	

Specimen A-6
40 ± 12 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.046	
18,000	0.059	
19,800	0.062*	
30,600	0.099	
32,400	0.104	
34,200	0.110	
36,000	0.117	0.00001805
37,800	0.129	
39,600	0.139	
41,400	0.152	
43,200	0.164*	
45,000	0.177	
46,800	0.192	
48,600	0.209	
54,000	0.275	
63,000	0.480	
64,800	0.548	
66,000	Failed	

Specimen G-7
40 ± 12 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.041	
9,000	0.041	
18,000	0.049	
27,000	0.052	
36,000	0.073*	
45,000	0.087	0.00001024
54,000	0.113	
63,000	0.138*	
72,000	0.236	
81,000	0.401	
87,000	Failed	

Specimen G-9
40 ± 13 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.040	
5,400	0.040	
7,200	0.042	
10,800	0.044	
14,400	0.050	
16,200	0.051*	
18,000	0.054	
21,600	0.059	0.00001432
25,200	0.068	
28,800	0.077	
30,600	0.082*	
32,400	0.088	
36,000	0.102	
39,600	0.120	
41,400	0.130*	
43,200	0.141	
46,800	0.172	0.00002293
50,400	0.209	
52,200	0.231*	
54,000	0.259	
57,600	0.328	
61,200	0.418	Average of
64,800	0.577	2 Slopes
66,000	Failed	0.00001863

Specimen I-8
40 ± 13 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.040	
18,000	0.044	
34,200	0.083*	
36,000	0.091	
37,800	0.097	
39,600	0.105	
41,400	0.113	
43,200	0.123	
45,000	0.134	0.00001969
46,800	0.146	
48,600	0.158	
50,400	0.172	
52,200	0.186	
54,000	0.200	
55,800	0.221	
71,200	0.543	
72,000	0.722	
72,000	Failed	

Specimen J-9
40 ± 14 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.042	
9,000	0.042	
18,000	0.047*	
27,000	0.067	
35,100	0.100	0.00001877
36,900	0.107	
38,700	0.115*	
40,500	0.127*	
42,300	0.141	
44,100	0.160	0.00002607
45,900	0.175	
47,700	0.194	
49,500	0.218*	
54,000	0.294	
61,200	0.511	
62,100	0.559	
63,000	0.619	
64,000	Failed	Average of
		2 Slopes
		0.00002242

Specimen N-9
40 ± 16 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.043	
4,500	0.050	
9,000	0.077	
11,700	0.098*	
12,600	0.104	
13,500	0.113	
14,400	0.120	
15,300	0.130	
16,200	0.139	0.00003394
17,100	0.149	
18,000	0.160	
18,900	0.172	
19,800	0.185	
20,700	0.198*	
22,500	0.232	
27,000	0.348	
30,600	0.523	
31,500	0.608	
32,000	Failed	

Specimen I-1
40 ± 18 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.043	
4,500	0.043	
9,000	0.048*	
13,500	0.057	
18,000	0.069	0.00001705
22,500	0.082	
22,950	0.083*	
26,550	0.099*	
27,000	0.101	
27,900	0.110	
28,800	0.118	
29,700	0.125	0.00003258
30,600	0.131	Slope used
31,500	0.140	
32,400	0.151	
33,300	0.163	
34,200	0.175	
35,100	0.188*	
36,000	0.204	
40,500	0.325	
44,550	0.594	
45,000	Failed	

TABLE VII

RATE OF CRACK PROGRESSION FOR Ti - 8 Al - 1 Mo - 1 V ALLOY SHEET TESTED AT 0 MEAN STRESS AND VARIOUS ALTERNATING STRESSES STARTING CRACK LENGTH 0.095" NOMINAL

Specimen M-4
0 ± 33 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.095	
21,600	0.095	
23,400	0.100	
25,200	0.142*	
27,000	0.177	
28,800	0.220	
30,600	0.275	0.00005379
32,400	0.350	
34,200	0.423	
36,000	0.541*	
38,000	Failed	

Specimen E-6
0 ± 33 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.089	
63,000	0.089*	
64,800	0.105	
66,600	0.123	
68,400	0.160	
70,200	0.199	0.00004799
72,000	0.247	
73,800	0.298	
75,600	0.364	
77,400	0.437*	
79,200	0.534	
81,000	0.681	
82,000	Failed	

Specimen N-7
0 ± 31 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.102	
9,000	0.102	
10,800	0.113*	
12,600	0.153	
14,400	0.212	0.00007580
16,200	0.290	
18,000	0.397*	
19,800	0.538	
22,000	Failed	

Specimen D-13
0 ± 34 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.0925	
21,600	0.0925	
23,400	0.095 *	
25,200	0.115	
27,000	0.142	0.00005093
28,800	0.176	
30,600	0.221*	
32,400	0.277	
34,200	0.348	
36,000	0.448	
37,800	0.598	
39,000	Failed	

Specimen A-1
0 ± 36 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.095	
27,000	0.095	
28,800	0.097*	
30,600	0.105	
32,400	0.122	0.00003307
34,200	0.142	
36,000	0.163	
36,900	0.175*	
37,800	0.191	
39,600	0.225	
41,400	0.274	
43,200	0.330	
45,000	0.410	
46,800	0.518	
49,000	Failed	

Specimen I-13
0 ± 36 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.0995	
36,000	0.0995	
36,900	0.112	
37,800	0.140*	
38,700	0.162	
39,600	0.187	
40,500	0.215	0.00006712
41,400	0.245	
42,300	0.278	
43,200	0.320	
44,100	0.371	
45,000	0.426*	
45,900	0.495	
46,800	0.582	
47,000	Failed	

Specimen D-11
0 ± 38 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.098	
900	0.103	
1,350	0.110	
1,800	0.116	
2,250	0.124*	
2,700	0.134	
3,150	0.148	
3,600	0.162	
4,050	0.176	0.00008978
4,500	0.194	
4,950	0.212	
5,400	0.232	
6,300	0.284	
7,200	0.345*	
8,100	0.418	
9,000	0.520	
10,000	Failed	

Specimen K-4
0 ± 38 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.095	
1,800	0.095	
2,700	0.100	
3,600	0.114	
4,500	0.130*	
5,400	0.156	
6,300	0.184	
7,200	0.222	0.00008542
8,100	0.263	
9,000	0.318	
9,900	0.376*	
10,800	0.450	
11,700	0.554	
13,000	Failed	

Specimen A-11
0 ± 40 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.095	
1,800	0.095	
2,700	0.115	
3,600	0.140*	
4,500	0.178	
5,400	0.224	0.00011290
6,300	0.282	
7,200	0.359	
8,100	0.451*	

TABLE VIII

RATE OF CRACK PROGRESSION FOR Ti - 8 Al - 1 Mo - 1 V ALLOY SHEET
TESTED AT 20 KSI MEAN STRESS AND VARIOUS ALTERNATING STRESSES
STARTING CRACK LENGTH 0.095" NOMINAL

Specimen G-5
20 ± 22 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.087	
1,135,000	0.087	
1,136,800	0.094	
1,138,600	0.105*	
1,140,400	0.123	
1,142,200	0.147	0.00004338
1,144,000	0.177	
1,145,800	0.212	
1,147,600	0.258*	
1,149,400	0.322	
1,151,200	0.401	
1,153,000	0.542	
1,153,000	Failed	

Specimen H-4
20 ± 24 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.094	
76,950	0.094	
77,400	0.110	
78,300	0.120	
79,200	0.128*	
80,100	0.132	
81,000	0.138	0.00001909
81,900	0.144	
82,800	0.151	
83,700	0.156*	
84,600	0.168*	
85,500	0.180	
86,400	0.199	0.00003818
87,300	0.214	
90,000	0.270*	
94,500	0.449	Average of
96,300	0.600	2 Slopes
97,000	Failed	0.00002864

Specimen G-3
20 ± 24 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.095	
922,600	0.095	
924,400	0.114	
926,200	0.120	
928,000	0.132*	
929,800	0.154	
931,600	0.189	0.00004407
933,400	0.226	
935,200	0.268	
937,000	0.329*	
938,800	0.405	
940,600	0.526	
941,000	Failed	

Specimen H-2
20 ± 26 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.092	
18,000	0.092	
22,500	0.094	
23,400	0.103	
24,300	0.108*	
25,200	0.119	
26,100	0.138	
27,000	0.153	0.00005482
27,900	0.171	
28,800	0.191	
29,700	0.213	
31,500	0.268*	
36,000	0.517	
37,000	Failed	

Specimen L-13
20 ± 26 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.101	
18,000	0.101	
19,800	0.103*	
21,600	0.120	
23,400	0.160	0.00005152
25,200	0.199	
27,000	0.242*	
28,800	0.303	
30,600	0.381	
32,400	0.500	
33,000	Failed	

Specimen A-14
20 ± 30 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.098	
9,000	0.098	
9,900	0.099	
10,800	0.105	
11,700	0.112*	
12,600	0.130	
13,500	0.147	0.00006903
14,400	0.170	
15,300	0.197	
16,200	0.229*	
17,100	0.267	
18,000	0.314	
18,900	0.375	
19,800	0.451	
20,700	0.585	
22,000	Failed	

Specimen F-10
20 ± 30 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.094	
27,450	0.094	
27,900	0.097	
28,350	0.105	
28,800	0.114	
29,250	0.119	
29,700	0.130*	
30,150	0.139	
30,600	0.147	
31,050	0.156	
31,500	0.167	0.00006165
31,950	0.179	
32,400	0.191	
32,850	0.203	
33,300	0.217	
33,750	0.231*	
36,000	0.321	

Specimen K-3
20 ± 33 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.096	
2,250	0.096	
2,700	0.097	
3,600	0.099	
4,500	0.107	
5,400	0.117	
6,300	0.130	
6,750	0.138*	
7,200	0.148	
8,100	0.171	0.00007037
9,000	0.199	
9,900	0.230	
10,800	0.266*	
11,700	0.310	
12,600	0.368	
13,500	0.453	
14,400	0.602	
15,000	Failed	

Specimen F-2
20 ± 33 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.108	
2,700	0.108	
3,600	0.114	
4,500	0.120	
5,400	0.132	
6,300	0.146	
6,750	0.156*	
7,200	0.168	
8,100	0.193	
9,000	0.230	0.00007808
9,900	0.273	
10,350	0.298*	
11,700	0.404	
12,600	0.538	
13,000	Failed	

TABLE IX

RATE OF CRACK PROGRESSION FOR Ti - 8 Al - 1 Mo - 1 V ALLOY SHEET
TESTED AT 40 KSI MEAN STRESS AND VARIOUS ALTERNATING STRESSES
STARTING CRACK LENGTH 0.095" NOMINAL

Specimen D-6
40 ± 8 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.090	
181,800	0.090	
189,000	0.100	
196,200	0.108	
203,400	0.111*	
210,600	0.112	
217,800	0.125	
225,000	0.138	0.000005693
232,200	0.152	
239,400	0.169	
246,600	0.185	
253,800	0.205*	
270,000	0.274	
288,000	0.393	
302,400	0.618	
304,000	Failed	

Specimen B-2
40 ± 8 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.102	
18,000	0.105	
27,000	0.106	
36,000	0.112	
45,000	0.118	
54,000	0.148*	
63,000	0.167	
72,000	0.184	0.000005832
81,000	0.208	
90,000	0.240*	
99,000	0.284	
108,000	0.344	
117,000	0.427	
126,000	0.572	
130,000	Failed	

Specimen C-3
40 ± 10 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.104	
17,100	0.104	
18,000	0.108*	
21,600	0.118	
25,200	0.129	
28,800	0.140	
32,400	0.156	0.0000110
36,000	0.172	
39,600	0.185	
43,200	0.204	
45,000	0.214*	
54,000	0.282	
63,000	0.394	
72,000	0.615	
74,000	Failed	

Specimen L-12
40 ± 10 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.093	
25,400	0.093	
26,750	0.099	
29,000	0.112*	
31,250	0.119	
33,500	0.128	
35,750	0.137	
38,000	0.146	0.00001265
40,250	0.157	
42,500	0.167	
44,750	0.178	
47,000	0.191	
49,250	0.202*	
51,500	0.216	
56,000	0.247	
60,500	0.279	
65,000	0.330	
69,500	0.389	
74,000	0.466	
78,500	0.595	
80,000	Failed	

Specimen L-11
40 ± 10 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.093	
35,100	0.093	
36,000	0.100	
38,250	0.105	
40,050	0.106*	
40,500	0.110	
42,750	0.114	
45,000	0.118	0.000009538
47,250	0.123	
49,500	0.130	
51,750	0.136	
54,000	0.144*	
56,250	0.151	
58,500	0.160	
60,750	0.169	
63,000	0.181	
65,250	0.191	
67,500	0.201	
72,000	0.224	
81,000	0.301	
90,000	0.426	
94,500	0.550	
96,000	Failed	

Specimen N-2
40 ± 12 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.104	
10,800	0.104	
12,600	0.112	
14,400	0.121	
16,200	0.129	
18,000	0.136	
19,800	0.145*	
21,600	0.157	
23,400	0.172	0.00001992
25,200	0.187	
27,000	0.202	
31,500	0.248*	
36,000	0.316	
40,500	0.409	
45,000	0.575	
46,000	Failed	

Specimen G-2B
40 ± 12 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.097	
8,550	0.097	
9,000	0.098	
9,450	0.102	
11,250	0.112*	
13,050	0.120	
14,850	0.128	
16,650	0.136	
18,450	0.143	0.00001562
20,250	0.155	
22,050	0.164	
23,850	0.180	
25,650	0.188*	
27,450	0.208	
31,050	0.246	
36,000	0.316	
40,500	0.409	
42,750	0.488	
46,000	Failed	

Specimen K-5B
40 ± 12 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.094	
4,950	0.094	
5,400	0.095	
7,200	0.103	
9,000	0.108*	
10,800	0.117	
12,600	0.124	
14,400	0.132	
16,200	0.141	0.00001718
18,000	0.151	
19,800	0.161	
21,600	0.177	
23,400	0.191	
25,200	0.205*	
27,000	0.228	
31,500	0.285	
36,000	0.364	
40,500	0.470	
44,000	Failed	

Specimen E-8
40 ± 14 KSI

Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N}$
0	0.096	
3,600	0.096	
4,050	0.103	
6,300	0.109	
8,100	0.116*	
9,900	0.127	
11,700	0.140	0.00002173
13,500	0.151	
15,300	0.166	
17,100	0.182*	
18,900	0.206	
20,700	0.232	
22,500	0.262	0.00003053
24,300	0.299	
26,100	0.341	
27,000	0.365*	
27,800	0.394	
29,700	0.460	Average of
31,500	0.560	2 Slopes
32,000	Failed	0.00002613

TABLE X

SUMMARY OF AVERAGE CRACK PROPAGATION RATES

FOR TITANIUM 8-1-1 ALLOY

Gross Mean Stress s_m KSI	Gross Alternating Stress s_a KSI	K x 10^6 (Geometric Mean)	N Number of Points
0	30	32.07	2
	32	30.27	1
	33	52.01	5
	34	36.78	6
	35	49.77	2
	36	43.48	6
	38	61.56	4
	39	52.35	1
	40	65.95	3
20	20	31.43	4
**	22	43.38	1
	23	23.46	2
	24	38.94	8
	26	47.25	5
	28	50.35	1
	30	65.03	4
	33	78.61	4
40	6	2.45	1
	8	4.93	13
	10	10.31	10
	11	14.30	2
	12	14.95	13
	13	19.16	2
	14	24.20	2
	16	33.94	1
	18	34.47	2

** Single point omitted because it was found to be out of statistical control.

TABLE XI

CRACK GENERATION - PHASE III

Nominal Crack Length In.	Specimen	Area In.^{2}	Approx. Cycles @ 65±50 KSI	Approx. Cycles @ 60±40 KSI	Crack Length Inches	Approx. Cycles @ 50±30 KSI	Final Crack Length, In. Front	Back	Remarks
0.042	A-3	0.042		12,000	0.0171	7,000	0.0284	0.0455	
	A-8	0.044		12,000	0.0129	22,000	0.0535	0.0353	
	A-10	0.044		16,000	0.0171	10,500	0.0374	0.0518	
	B-1	0.043		15,000	0.0160	10,000	0.0401	0.0455	
	B-3	0.042		15,000	0.0144	26,000	0.0445	0.0321	
	B-10	0.046		9,000	0.0150	14,500	0.0401	0.0363	
	B-12	0.042		10,000	0.0235	5,500	0.0460	0.0439	
	C-14	0.041		10,000	0.0214	12,000	0.0444	0.0401	
	D-9	0.043		17,000	0.0134	20,000	0.0401	0.0482	
	D-10	0.043		19,000	0.0176	14,000	0.0412	0.0561	
	D-14	0.041		16,000	0.0150	25,000	0.0455	0.0246	
	E-5	0.043		15,000	0.0155	20,500	0.0412	0.0353	
	G-1	0.042		9,000	0.0134	11,000	0.0449	0.0310	
	H-7	0.044		13,000	0.0128	15,000	0.0390	0.0422	
	H-11	0.042		17,000	0.0166	18,000	0.0455	0.0299	
	H-12	0.042		18,000	0.0176	14,000	0.0455	0.0321	
	I-12	0.042		10,000	0.0224	9,500	0.0423	0.0455	
	J-5	0.043		9,000	0.0241	8,000	0.0401	0.0455	
	J-8	0.043		18,000	0.0134	28,000	0.0396	0.0460	
	J-12	0.042		16,000	0.0160	22,000	0.0428	0.0423	
	L-1	0.039		12,000	0.0230	7,000	0.0444	0.0390	
	M-3	0.042		9,000	0.0166	21,000	0.0444	0.0406	
	M-7	0.046		8,000	0.0160	9,000	0.0417	0.0428	
	N-3	0.042		17,000	0.0144	18,000	0.0401	0.0412	
0.095	A-4	0.043		37,000	0.0176	27,000	0.0802	0.0947	
	B-4	0.043	12,000		0.0080	26,000	0.0963	0.0775	
	B-5	0.043		15,000	0.0150	16,000	0.0864	0.1017	
	C-4	0.043		15,000	0.0144	20,000	0.0742	0.0952	
	C-5	0.044		16,000	0.0214	18,000	0.0760	0.0926	
	C-8	0.044		12,000	0.0246	16,500	0.0909	0.0609	
	C-9	0.044	12,000		0.0322	7,000	0.1145	0.1145	
	C-11	0.043		17,000	0.0107	28,000	0.0615	0.0952	
	D-5	0.043		15,000	0.0134	26,000	0.0770	0.0920	
	E-4	0.043		11,000	0.0171	27,000	0.0872	0.0969	
	E-12	0.042		12,000	0.0363	6,000	0.1048	0.1023	
	E-13	0.041		12,000	0.0171	27,000	0.0947	0.0824	
	F-7	0.043	13,000		0.0198	13,000	0.0973	0.0888	
	F-13	0.044		11,000	0.0225	15,500	0.0936	0.0750	
	G-8	0.044		10,000	0.0150	13,000	0.0540	0.0893	
	H-5	0.044		16,000	0.0176	3,000	0.0722	0.0995	.010" Hole
	H-13	0.042	10,000		0.0123	19,500	0.0995	0.0920	
	I-5	0.043		19,000	0.0134	18,500	0.0781	0.0910	
	J-7	0.044		14,000	0.0134	17,000	0.0845	0.0989	
	K-7	0.044		31,000	0.0171	9,000	0.0663	0.0942	
	K-8	0.044		12,000	0.0155	14,000	0.0813	0.0942	
	K-10	0.044		10,000	0.1104	-	0.1104	0.1163	All Growth @ 60±40 KSI
	L-3	0.042		12,000	0.0150	9,000	0.0652	0.0936	
	L-4	0.042		37,000	0.0118	22,000	0.0663	0.0923	
	L-5	0.043	11,000		0.0118	28,000	0.0973	0.0647	
	L-8	0.043		15,000	0.0208	14,000	0.0936	0.0658	
	M-8	0.044		15,000	0.0139	25,000	0.1080	0.1193	
	N-6	0.044		18,000	0.0160	10,500	0.0995	0.1198	
	N-13	0.041		11,000	0.0171	21,000	0.0969	0.0872	
	P-1	0.041		15,000	0.0123	20,000	0.0717	0.0952	

TABLE XII

PHASE III TESTING

Specimen	Condition For Generation of Crack			Conditions For Propagation of Crack						
	Approx. Cycles 65±50 Ksi	Approx. Cycles 60±40 Ksi	Approx. Cycles 50±30 Ksi	Gross Mean Stress Ksi	Gross Alternating Stress, Ksi	Cycles: At This Stress Level	Cycles: Total	Crack Length In.: Start	Crack Length In.: End	Cycles To Start Of Crack Growth
F-7	13,000	-	13,000	40	12	8,000	8,000	.098	.110	Negl.
					10	13,000	21,000	.110	.140	Negl.
					8	86,000	107,000	.140	Failure	Negl.
B-5	-	15,000	16,000	40	12	16,000	16,000	.086	.128	7,200
					8	18,000	34,000	.128	.165	Negl.
					10	37,000	71,000	.165	Failure	Negl.
E-13		12,000	27,000	40	8	48,000	48,000	.095	.124	21,600
					10	13,000	61,000	.124	.162	Negl.
					12	24,000	85,000	.162	Failure	Negl.
K-8		12,000	14,000	40	8	107,000	107,000	.094	.136	63,000
					12	8,000	115,000	.136	.179	Negl.
					10	36,000	151,000	.179	Failure	Negl.

TABLE XIII

DELAY BEFORE START OF CRACK GROWTH Ti - 8 Al - 1 Mo - 1 V ALLOY SHEET
STARTING CRACK LENGTH 0.042 NOMINAL

Specimen	Mean Stress KSI	Original Crack Length In.	First Alternating Stress, KSI	Resulting Crack Length In.	Second Alternating Stress, KSI	Delay Before Start Of Crack Growth Cycles
A-8	0	0.035	40	0.036	30	57,600
H-7		0.039	40	0.047	32	36,000
D-14		0.0455	40	0.061	34	1,800
C-14		0.044	45	0.057	34	5,400
M-7		0.043	45	0.0485	36	14,400
A-10		0.037	45	0.054	39	Negligible
E-5		0.041	60	0.048	34	321,000 Did Not Grow
					38	122,400
J-5	20	0.040	35	0.0485	18	9,000
A-3		0.0455	35	0.065	20	1,800
J-12		0.043	35	0.057	24	1,000 *
D-10		0.041	45	0.055	20	7,200
I-12		0.042	45	0.055	22	19,800
B-3		0.0445	45	0.0565	24	1,800
B-10		0.040	55	0.075	24	19,800
L-1		0.044	55	0.082	28	7,200
H-12	40	0.0455	20	0.055	8	7,200
N-3		0.041	20	0.0495	10	3,600
G-1		0.045	20	0.061	12	1,800
D-9		0.040	30	0.051	8	39,600
B-1		0.040	30	0.051	10	19,800
H-11		0.0455	30	0.049	12	7,200
J-8		0.040	35	0.053	12	10,800
B-12		0.046	35	0.056	15	5,400
M-3		0.044	35	0.048	18	1,800

* Extrapolated Value

TABLE XIV

DELAY BEFORE START OF CRACK GROWTH Ti - 8 Al - 1 Mo - 1 V ALLOY SHEET
STARTING CRACK LENGTH 0.095" NOMINAL

Specimen	Mean Stress KSI	Original Crack Length In.	First Alternating Stress, KSI	Resulting Crack Length In.	Second Alternating Stress, KSI	Delay Before Start Of Crack Growth - Cycles
L-5	0	0.097	40	0.122	30	7,200
D-5		0.0925	40	0.103	33	1,800
N-13		0.087	45	0.121	31	12,600
C-9		0.1145	45	0.131	33	21,600
L-4		0.092	45	0.116	36	10,800
K-10		0.110	50	0.119	34	256,000 No Growth
					38	200,000 No Growth
M-8		0.108	60	0.128	30	360,000 No Growth
					33	1,548,000 No Growth
F-13		0.094	60	0.104	33	1,800
E-4		0.087	60	0.098	38	18,000
B-4		0.096	80	0.112	33	225,000 No Growth
					38	17,000 No Growth-Broke in Grip
A-4	20	0.095	35	0.105	16	23,400
I-5		0.091	35	0.124	20	1,800
L-3		0.094	35	0.111	24	1,800
L-8		0.094	45	0.132	20	7,200
H-5		0.0995	45	0.114	24	5,400
C-4		0.095	45	0.135	26	1,200 * Extrapolated
K-7		0.094	50	0.109	24	18,000
E-12		0.105	50	0.121	28	1,800
E-13	40	0.095	8	0.124	10	Negligible
			10	0.161	12	"
K-8		0.094	8	0.136	12	"
			12	0.179	10	"
B-5		0.086	12	0.128	8	"
			8	0.165	10	"
F-7		0.098	12	0.110	10	"
			10	0.140	8	"
G-8		0.089	15	0.106	6	10,800
C-11		0.095	15	0.114	8	2,700
C-5		0.092	20	0.111	8	5,400
N-6		0.0995	20	0.121	8	7,200
C-8		0.091	20	0.102	10	3,600
H-13		0.0995	30	0.121	8	21,600
J-7		0.099	30	0.117	8	23,400
P-1		0.095	30	0.115	12	5,400

TABLE XV

RATE OF CRACK PROGRESSION FOR Ti - 8 Al - 1 Mo - 1 V ALLOY SHEET
TESTED AT 0 MEAN STRESS AND VARIOUS ALTERNATING STRESSES
STARTING CRACK LENGTH - .042" NOMINAL

Specimen A-8

Alternating Stress, KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
40	0	0.035	
	2,000@	0.036	
30	0	0.036	
	57,600	0.036	
	59,400	0.038	
	61,200	0.046	
	63,000	0.051	
	64,800	0.066	
	66,600	0.084 *	
	68,400	0.100	
	70,200	0.122	
	72,000	0.148	45.56
	73,800	0.177	
	75,600	0.215	
	77,400	0.258	
	79,200	0.315 *	
	81,000	0.388	
	82,800	0.483	
	84,600	0.630	
	85,000	Failed	

Specimen H-7

Alternating Stress, KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
40	0	0.039	
	13,000@	0.047	
32	0	0.047	
	36,000	0.047	
	37,800	0.052	
	39,600	0.056	
	43,200	0.070 *	
	46,800	0.089	
	50,400	0.114	30.27
	54,000	0.148	
	57,600	0.191 *	
	61,200	0.253	
	64,800	0.348	
	68,400	0.489	
	71,000	Failed	

Specimen D-14

Alternating Stress, KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
40	0	0.0455	
	6,000@	0.061	
34	0	0.061	
	1,800	0.061	
	3,600	0.066	
	5,400	0.068	
	7,200	0.070	
	9,000	0.084 *	
	10,800	0.094	
	12,600	0.105	30.81
	14,400	0.121	
	16,200	0.140 *	
	18,000	0.166	
	19,800	0.201	
	21,600	0.249	
	23,400	0.313	
	25,200	0.414	
	27,000	0.514	
	28,800	0.630	
	31,000	Failed	

@ cycles inaccurate because of starts and stops

Specimen C-14

Alternating Stress, KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
45	0	0.044	
	6,000@	0.057	
34	0	0.057	
	5,400	0.057	
	7,200	0.062	
	9,000	0.064	
	10,800	0.072	
	12,600	0.077 *	
	14,400	0.084	
	16,200	0.094	23.14
	18,000	0.1035	
	19,800	0.113 *	
	21,600	0.128	
	23,400	0.144	29.41
	25,200	0.163	
	27,000	0.184 *	
	28,800	0.212	
	30,600	0.245	
	32,400	0.282	
	34,200	0.329	
	36,000	0.389	Average 26.27
	37,800	0.469	
	39,600	0.583	
	41,000	Failed	

TABLE XV - Continued

RATE OF CRACK PROGRESSION FOR Ti - 8 Al - 1 Mo - 1 V ALLOY SHEET
TESTED AT 0 MEAN STRESS AND VARIOUS ALTERNATING STRESSES
STARTING CRACK LENGTH 0.042" NOMINAL

Specimen M-7

Alternating Stress, KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
45	0	0.043	
	3,000@	0.0485	
36	0	0.0485	
	14,400	0.0485	
	16,200	0.051	
	18,000	0.059	
	19,800	0.065 *	
	21,600	0.0745	
	23,400	0.084	
	25,200	0.098	33.09
	27,000	0.112	
	28,800	0.128	
	30,600	0.148 *	
	32,400	0.174	
	34,200	0.202	
	36,000	0.238	
	37,800	0.279	
	39,600	0.326	
	41,400	0.386	
	43,200	0.468	
	45,000	0.584	
	46,000	Failed	

Specimen A-10

Alternating Stress, KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
45	0	0.037	
	9,000@	0.054	
39	0	0.054	
	1,800	0.073 *	
	3,600	0.093	
	5,400	0.112	52.35
	7,200	0.140	
	9,000	0.173	
	10,800	0.216 *	
	12,600	0.275	
	14,400	0.356	
	16,200	0.488	
	17,000	Failed	

Specimen E-5

Alternating Stress, KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
60	0	0.041	
	2,000@	0.048	
34	0	0.048	
	321,000	0.048	
38	0	0.048	
	122,400	0.048	
	124,200	0.052	
	126,000	0.060 *	
	129,600	0.065	
	133,200	0.070	8.686
	136,800	0.073	
	140,400	0.079	
	144,000	0.086 *	
	147,600	0.103	
	151,200	0.125 *	
	154,800	0.157	30.52
	158,400	0.204	
	162,000	0.267 *	
	165,000	0.374	
	169,200	0.441	
	170,000	Failed	

@ cycles inaccurate because of starts and stops

TABLE XVI

RATE OF CRACK PROGRESSION FOR Ti - 8 Al - 1 Mo - 1 V ALLOY SHEET
TESTED AT 20 KSI MEAN STRESS AND VARIOUS ALTERNATING STRESSES
STARTING CRACK LENGTH 0.042" NOMINAL

Specimen J-5

Alternating Stress, KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
35	0	0.040	
	6,000[a]	0.0485	
18	0	0.0485	
	9,000	0.0485	
	10,800	0.050	
	12,600	0.052	
	14,400	0.059	
	16,200	0.063	
	18,000	0.067 *	
	21,600	0.079	
	25,200	0.094	20.90
	28,800	0.110	
	32,400	0.134 *	
	36,000	0.163	
	39,600	0.211	
	43,200	0.268	
	46,800	0.350	
	50,400	0.465	
	52,200	0.558	
	54,000	Failed	

Specimen A-3

Alternating Stress, KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
35	0	0.0455	
	3,000[a]	0.065	
20	0	0.065	
	1,800	0.065	
	3,600	0.068	
	5,400	0.0715 *	
	7,200	0.081	
	9,000	0.089	
	10,800	0.101	29.53
	12,600	0.114	
	14,400	0.130	
	16,200	0.149 *	
	18,000	0.176	
	19,800	0.208	
	21,600	0.239	
	23,400	0.285	
	25,200	0.341	
	27,000	0.416	
	28,800	0.525	
	31,000	Failed	

Specimen J-12

Alternating Stress, KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
35	0	0.043	
	3,000[a]	0.057	
24	0	0.057	
	1,800	0.061	
	3,600	0.070 *	
	5,400	0.082	
	7,200	0.096	39.17
	9,000	0.111	
	10,800	0.134 *	
	12,600	0.162	
	14,400	0.194	46.36
	16,200	0.235	
	18,000	0.289 *	
	19,800	0.355	
	21,600	0.446	Average 42.76
	23,400	0.589	
	24,000	Failed	

Specimen D-10

Alternating Stress, KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
45	0	0.041	
	3,000[a]	0.055	
20	0	0.055	
	7,200	0.055	
	9,000	0.057 *	
	10,800	0.067	
	12,600	0.080	
	14,400	0.093	
	16,200	0.106	36.34
	18,000	0.122	
	19,800	0.142	
	21,600	0.162	
	23,400	0.188	
	25,200	0.219	
	27,000	0.257 *	
	28,800	0.305	
	30,600	0.359	
	32,400	0.435	
	34,200	0.542	
	37,000	Failed	

TABLE XVI - Continued

RATE OF CRACK PROGRESSION FOR Ti - 8 Al - 1 Mo - 1 V ALLOY SHEET
TESTED AT 20 KSI MEAN STRESS AND VARIOUS ALTERNATING STRESSES
STARTING CRACK LENGTH 0.042" NOMINAL

Specimen I-12

Alternating Stress, KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
45	0	0.042	
	1,000⊗	0.055	
22	0	0.055	
	19,800	0.055	
	21,600	0.057	
	23,400	0.059	
	25,200	0.073 *	
	27,000	0.083	
	28,800	0.094	
	30,600	0.109	32.30
	32,400	0.122	
	34,200	0.142	
	36,000	0.163 *	
	37,800	0.189	
	39,600	0.218	
	41,400	0.255	
	43,200	0.301	
	45,000	0.358	
	46,800	0.426	
	48,600	0.531	
	50,000	Failed	

Specimen B-3

Alternating Stress, KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
45	0	0.0445	
	2,000⊗	0.0565	
24	0	0.0565	
	1,800	0.0565	
	3,600	0.058	
	5,400	0.060	
	7,200	0.065 *	
	9,000	0.074	
	10,800	0.084	32.70
	12,600	0.096	
	14,400	0.111	
	16,200	0.128 *	
	18,000	0.152	
	19,800	0.178	
	21,600	0.212	
	23,400	0.256	
	25,200	0.314	
	27,000	0.386	
	28,800	0.500	
	30,000	Failed	

Specimen B-10

Alternating Stress, KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
55	0	0.040	
	2,000⊗	0.075	
24	0	0.075	
	19,800	0.075	
	21,600	0.091 *	
	23,400	0.109	
	25,200	0.128	42.16
	27,000	0.152	
	28,800	0.178	
	30,600	0.218 *	
	32,400	0.265	
	34,200	0.326	
	36,000	0.400	
	37,800	0.524	
	39,000	Failed	

Specimen L-1

Alternating Stress, KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
55	0	0.044	
	3,000⊗	0.082	
28	0	0.082	
	7,200	0.082	
	9,000	0.094	
	10,800	0.131 *	
	12,600	0.164	50.35
	14,400	0.199	
	16,200	0.245 *	
	18,000	0.306	
	19,800	0.389	
	21,600	0.512	
	22,000	Failed	

TABLE XVII

RATE OF CRACK PROGRESSION FOR Ti - 8 Al - 1 Mo - 1 V ALLOY SHEET
TESTED AT 40 KSI MEAN STRESS AND VARIOUS ALTERNATING STRESSES
STARTING CRACK LENGTH 0.042" NOMINAL

Specimen H-12

Alternating Stress, KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
20	0	0.0455	
	4,000@	0.055	
8	0	0.055	
	7,200	0.055	
	10,800	0.058	
	18,000	0.059	
	25,200	0.063*	
	36,000	0.066	
	54,000	0.074	2.318
	72,000	0.079	
	90,000	0.089	
	108,000	0.098*	
	126,000	0.116	4.190
	144,000	0.136	
	162,000	0.165*	
	180,000	0.205	
	198,000	0.281	Average 3.264
	216,000	0.408	
	231,000	Failed	

Specimen N-3

Alternating Stress, KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
20	0	0.041	
	5,000@	0.0495	
10	0	0.0495	
	3,600	0.0495	
	5,400	0.0505	
	7,200	0.053*	
	14,400	0.059	
	21,600	0.063	
	28,800	0.068	
	36,000	0.076	5.858
	43,200	0.083	
	50,400	0.091*	
	57,600	0.102*	
	64,800	0.116	8.671
	72,000	0.134	
	79,200	0.157*	
	86,400	0.190	
	97,200	0.256	Average 7.265
	108,000	0.366	
	118,800	0.630	
	119,000	Failed	

Specimen G-1

Alternating Stress, KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
20	0	0.045	
	5,000@	0.061	
12	0	0.061	
	1,800	0.061	
	3,000	0.062*	
	7,200	0.066	
	10,800	0.071	
	14,400	0.076	8.580
	18,000	0.081	
	21,600	0.088	
	25,200	0.095	
	28,800	0.102*	
	32,400	0.112	
	36,000	0.124*	
	39,600	0.140	14.99
	43,200	0.160	
	46,800	0.180*	
	50,400	0.211	
	54,000	0.249	
	57,600	0.301	
	61,200	0.365	
	64,800	0.458	Average 11.78
	68,000	Failed	

Specimen D-9

Alternating Stress, KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
30	0	0.040	
	1,000	0.051	
8	0	0.051	
	39,600	0.051	
	41,400	0.055	
	50,400	0.064*	
	63,000	0.072	
	81,000	0.084	3.716
	99,000	0.096	
	117,000	0.111	
	135,000	0.132*	
	153,000	0.160	
	171,000	0.202	
	189,000	0.271	
	207,000	0.394	
	216,000	0.502	

Specimen B-1

Alternating Stress, KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
30	0	0.040	
	1,000@	0.051	
10	0	0.051	
	19,800	0.051	
	21,600	0.053	
	28,800	0.061	
	36,000	0.066	
	43,200	0.072*	
	50,400	0.082	8.616
	57,600	0.096	
	64,800	0.109	
	68,400	0.116*	
	72,000	0.128	10.60
	79,200	0.151	
	86,400	0.180*	
	93,600	0.220	
	100,800	0.276	
	108,000	0.357	
	115,200	0.500	
	119,000	Failed	Average 9.608

@ Cycles inaccurate because of starts and stops

TABLE XVII - Continued

RATE OF CRACK PROGRESSION FOR Ti - 8 Al - 1 Mo - 1 V ALLOY SHEET
TESTED AT 40 KSI MEAN STRESS AND VARIOUS ALTERNATING STRESSES
STARTING CRACK LENGTH 0.042" NOMINAL

Specimen H-11

Alternating Stress, KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
30	0	0.0455	
	1,000⊗	0.049	
12	0	0.049	
	7,200	0.049	
	9,000	0.051	
	10,800	0.051	
	14,400	0.055	
	18,000	0.059	
	21,600	0.061 *	
	25,200	0.066	7.635
	32,400	0.076	
	39,600	0.081	
	46,800	0.095 *	
	54,000	0.115	11.26
	61,200	0.138 *	
	68,400	0.177	
	75,600	0.238	Average
	82,800	0.339	9.447
	90,000	0.517	
	94,000	Failed	

Specimen J-8

Alternating Stress, KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
35	0	0.040	
	1,000⊗	0.053	
12	0	0.053	
	10,800	0.053	
	12,600	0.056	
	14,400	0.060	
	16,200	0.063	
	18,000	0.066	
	21,600	0.076	
	25,200	0.084 *	
	28,800	0.094	14.32
	32,400	0.106	
	36,000	0.118	
	39,600	0.135 *	
	43,200	0.159	
	46,800	0.182	
	54,000	0.251	
	61,200	0.364	
	68,400	0.582	
	70,000	Failed	

Specimen B-12

Alternating Stress, KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
35	0	0.046	
	2,000⊗	0.056	
15	0	0.056	
	5,400	0.056	
	7,200	0.062	
	9,000	0.069	
	10,800	0.076	
	12,600	0.082	
	14,400	0.089 *	
	16,200	0.099	
	18,000	0.109	23.84
	19,800	0.120	
	21,600	0.133	
	23,400	0.145	
	25,200	0.161 *	
	27,000	0.181	
	28,800	0.209	
	30,600	0.240	
	32,400	0.275	
	34,200	0.309	
	36,000	0.365	
	37,800	0.424	
	39,600	0.516	
	41,000	Failed	

Specimen M-3

Alternating Stress, KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
35	0	0.044	
	1,000⊗	0.048	
18	0	0.048	
	1,800	0.048	
	3,600	0.050	
	5,400	0.053	
	7,200	0.059	
	9,000	0.069	
	10,800	0.078 *	
	12,600	0.090	
	14,400	0.105	36.45
	16,200	0.122	
	18,000	0.142	
	19,800	0.166*	
	21,600	0.198	
	23,400	0.236	
	25,200	0.288	
	27,000	0.345	
	28,800	0.426	
	30,600	0.562	
	31,000	Failed	

⊗ cycles inaccurate because of starts and stops

TABLE XVIII

RATE OF CRACK PROGRESSION FOR Ti - 8 Al - 1 Mo - 1 V ALLOY SHEET
TESTED AT 0 MEAN STRESS AND VARIOUS ALTERNATING STRESSES
STARTING CRACK LENGTH 0.095" NOMINAL

Specimen L-5

Alternating Stress, KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
40	0	0.097	
	13,000@	0.122	
30	0	0.122	
	7,200	0.122	
	9,000	0.131*	
	10,800	0.144	
	12,600	0.160	23.33
	14,400	0.178	
	16,200	0.194	
	18,000	0.218	
	19,800	0.234*	
	21,600	0.270	
	23,400	0.303	
	25,200	0.344	
	27,000	0.392	
	28,800	0.450	
	30,600	0.526	
	34,000	Failed	

Specimen D-5

Alternating Stress, KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
40	0	0.0925	
	2,000@	0.103	
33	0	0.103	
	1,800	0.103	
	3,600	0.104	
	5,400	0.118*	
	7,200	0.147	
	9,000	0.175	47.07
	10,800	0.212	
	12,600	0.259	
	14,400	0.313*	
	16,200	0.390	
	18,000	0.478	
	19,800	0.612	
	21,000	Failed	

Specimen N-13

Alternating Stress, KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
45	0	0.087	
	7,000@	0.121	
31	0	0.121	
	12,600	0.121	
	14,400	0.126*	
	16,200	0.137	
	18,000	0.150	
	19,800	0.162	20.14
	21,600	0.171	
	23,400	0.191	
	25,200	0.207	
	27,000	0.226*	
	28,800	0.250	
	30,600	0.281	
	32,400	0.314	
	34,200	0.351	
	36,000	0.399	
	37,800	0.454	
	39,600	0.525	
	41,400	0.631	
	42,000	Failed	

Specimen C-9

Alternating Stress, KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
45	0	0.1145	
	8,000@	0.131	
33	0	0.131	
	21,600	0.131	
	23,400	0.148*	
	25,200	0.192	59.46
	27,000	0.241	
	28,800	0.310*	
	30,600	0.389	
	32,400	0.510	
	35,000	Failed	

@ Cycles inaccurate because of starts and stops

TABLE XVIII - Continued

RATE OF CRACK PROGRESSION FOR Ti - 8 Al - 1 Mo - 1 V ALLOY SHEET
TESTED AT 0 MEAN STRESS AND VARIOUS ALTERNATING STRESSES
STARTING CRACK LENGTH 0.095" NOMINAL

Specimen L-4

Alternating Stress, KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
45	0	0.092	
	16,000@	0.116	
36	0	0.116	
	10,800	0.116	
	12,600	0.130	
	14,400	0.153	
	16,200	0.164	
	18,000	0.172*	
	19,800	0.201	
	21,600	0.229	32.02
	23,400	0.256	
	25,200	0.296	
	27,000	0.334*	
	28,800	0.390	
	30,600	0.458	
	32,400	0.553	
	34,000	Failed	

Specimen K-10

Alternating Stress, KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
50	0	0.110	
	1,000@	0.119	No Growth
34	0	0.119	
	256,000	0.119	
38	0	0.119	
	200,000	0.119	

Specimen M-8

Alternating Stress, KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
60	0	0.108	
	2,000@	0.128	
30	0	0.128	No Growth
	360,000	0.128	
33	0	0.128	
	1,548,000	0.128	
		Broke In Grip	

Specimen F-13

Alternating Stress, KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
60	0	0.094	
	1,000	0.104	
33	0	0.104	
	1,800	0.104	
	3,600	0.108	
	5,400	0.126*	
	7,200	0.156	52.68
	9,000	0.195*	
	10,800	0.255	
	12,600	0.326	
	14,400	0.417	
	16,200	0.566	
	17,000	Failed	

Specimen E-4

Alternating Stress, KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
60	0	0.087	
	2,000	0.098	
38	0	0.098	
	18,000	0.098	
	19,800	0.101	
	21,600	0.125	
	23,400	0.153*	
	25,200	0.171	
	27,000	0.196	34.04
	28,800	0.228	
	30,600	0.269*	
	32,400	0.295	
	34,200	0.375	
	36,000	0.456	
	37,800	0.576	
	38,000	Failed	

Specimen B-4

Alternating Stress, KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
80	0	0.096	
	1,000	0.112	
33	0	0.112	No Growth
	225,000	0.112	
38	0	0.112	
	17,000	0.112	
		Broke in Grip	

@ Cycles inaccurate because of starts and stops

TABLE XIX

RATE OF CRACK PROGRESSION FOR Ti - 8 Al - 1 Mo - 1 V ALLOY SHEET
TESTED AT 20 KSI MEAN STRESS AND VARIOUS ALTERNATING STRESSES
STARTING CRACK LENGTH 0.095" NOMINAL

Specimen A-4

Alternating Stress KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
35	0	0.095	
	3,000@	0.105	
16	0	0.105	
	23,400	0.105	
	25,200	0.110	
	27,000	0.118*	
	28,800	0.128	
	30,600	0.141	
	32,400	0.152	21.22
	34,200	0.164	
	36,000	0.182	
	37,800	0.200*	
	39,600	0.223	
	41,400	0.249	
	43,200	0.280	
	45,000	0.313	
	46,800	0.360	
	48,600	0.415	
	50,400	0.484	
	52,200	0.585	
	53,000	Failed	

Specimen I-5

Alternating Stress KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
35	0	0.091	
	4,000@	0.124	
20	0	0.124	
	1,800	0.125	
	3,600	0.130	
	5,400	0.143*	
	7,200	0.158	
	9,000	0.179	27.60
	10,800	0.199	
	12,600	0.226*	
	14,400	0.259	
	16,200	0.300	
	18,000	0.351	
	19,800	0.413	
	21,600	0.496	
	23,400	0.637	
	24,000	Failed	

Specimen L-3

Alternating Stress KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
35	0	0.094	
	5,000@	0.111	
24	0	0.111	
	1,800	0.113	
	3,600	0.125	
	5,400	0.114*	
	7,200	0.169	41.42
	9,000	0.201	
	10,800	0.241*	
	12,600	0.292	
	14,400	0.363	
	16,200	0.446	
	18,000	0.590	
	19,000	Failed	

Specimen L-8

Alternating Stress KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
45	0	0.094	
	1,000@	0.132	
20	0	0.132	
	7,200	0.132	
	9,000	0.135	
	10,800	0.143*	
	12,600	0.160	29.97
	14,400	0.179	
	16,200	0.206*	
	18,000	0.235	
	19,800	0.273	35.97
	21,600	0.319	
	23,400	0.374*	
	25,200	0.445	
	27,000	0.544	
	29,000	Failed	Average 32.97

Specimen H-5

Alternating Stress KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
45	0	0.0995	
	1,500@	0.114	
24	0	0.114	
	5,400	0.114	
	7,200	0.122	
	9,000	0.134*	
	10,800	0.158	42.75
	12,600	0.187	
	14,400	0.228*	
	16,200	0.275	
	18,000	0.337	
	19,800	0.425	
	21,600	0.576	
	22,000	Failed	

Specimen C-4

Alternating Stress KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
45	0	0.095	
	2,000@	0.135	
26	0	0.135	
	1,800	0.140	
	3,600	0.159*	
	5,400	0.199	57.50
	7,200	0.250	
	9,000	0.325*	
	10,800	0.431	
	12,000	Failed	

Specimen K-7

Alternating Stress KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
50	0	0.094	
	1,000@	0.109	
24	0	0.109	
	18,000	0.109	
	19,800	0.123*	
	21,600	0.142	35.44
	23,400	0.165*	
	25,200	0.196	
	27,000	0.235	42.00
	28,800	0.278	
	30,600	0.331*	
	32,400	0.410	
	34,200	0.520	
	35,000	Failed	Average 38.72

Specimen E-12

Alternating Stress KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
50	0	0.105	
	1,000@	0.121	
28	0	0.121	
	1,800	0.141	
	3,600	0.178*	
	5,400	0.240	67.70
	7,200	0.312*	
	9,000	0.448	
	11,000	Failed	

@ cycles inaccurate because of starts and stops

TABLE XX

RATE OF CRACK PROGRESSION FOR Ti - 8 Al - 1 Mo - 1 V ALLOY SHEET
TESTED AT 40 KSI MEAN STRESS AND VARIOUS ALTERNATING STRESSES
STARTING CRACK LENGTH 0.095" NOMINAL

Specimen E-13

Alternating Stress, KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
8	0	0.095	
	21,600	0.095	
	23,400	0.098	
	27,000	0.103*	
	30,600	0.108	
	34,200	0.112	4.095
	37,800	0.116	
	43,200	0.120*	
	48,000	0.124	
10	0	0.124	
	1,800	0.126*	
	5,400	0.137	
	9,000	0.148	9.857
	12,600	0.161*	
12	0	0.162*	
	1,800	0.179	
	5,400	0.209	21.01
	9,000	0.240	
	12,600	0.298*	
	16,200	0.365	
	19,800	0.459	
	23,400	0.633	
	24,000	Failed	

Specimen K-8

Alternating Stress, KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
8	0	0.094	
	63,000	0.094	
	66,000	0.096	
	70,200	0.0985	
	75,600	0.100*	
	82,800	0.108	
	90,000	0.115	4.243
	97,200	0.122	
	104,400	0.113	
	107,000	0.136*	
12	0	0.136	
	1,800	0.139*	
	3,600	0.152	
	5,400	0.162	17.71
	7,200	0.171	
	8,000	0.179*	
10	0	0.179	
	1,800	0.182	
	5,400	0.201	
	9,000	0.219*	
	12,600	0.244	14.24
	16,200	0.274	
	21,600	0.331*	
	23,400	0.353	
	27,000	0.403	
	30,600	0.570	
	34,200	0.574	
	36,000	Failed	

Specimen B-5

Alternating Stress, KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
12	0	0.086	
	7,200	0.086*	
	9,000	0.094	
	10,800	0.103	21.09
	12,600	0.112	
	14,400	0.122*	
	16,000	0.128	
8	0	0.128*	
	1,800	0.131	
	3,600	0.134	
	5,400	0.137	5.577
	7,200	0.140	
	9,000	0.144	
	10,800	0.147	
	12,600	0.150	
	14,400	0.154*	
	16,200	0.161	
	18,000	0.165	
10	0	0.165	
	1,800	0.171	
	5,400	0.187	
	9,000	0.209*	
	12,600	0.234	
	16,200	0.264	14.59
	19,800	0.300	
	23,400	0.339*	
	27,000	0.391	
	30,600	0.466	
	34,200	0.558	
	37,000	Failed	

Specimen F-7

Alternating Stress, KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
12	0	0.098	
	3,600	0.098*	
	5,400	0.103	11.72
	7,200	0.108*	
	8,000	0.110	
10	0	0.110	
	1,800	0.113	
	3,600	0.115*	
	5,400	0.120	
	7,200	0.125	
	9,000	0.130	8.798
	10,800	0.135	
	12,600	0.138*	
	13,000	0.140	
8	0	0.140	
	1,800	0.142	
	5,400	0.148	
	9,000	0.152	
	12,600	0.157	
	16,200	0.164*	
	19,800	0.174	
	23,400	0.182	
	27,000	0.192	
	30,600	0.200	6.176
	34,200	0.210	
	37,800	0.222	
	45,000	0.247*	
	63,000	0.346	
	81,000	0.553	
	86,000	Failed	

TABLE XX - Continued

RATE OF CRACK PROGRESSION FOR Ti - 8 Al - 1 Mo - 1 V ALLOY SHEET
TESTED AT 40 KSI MEAN STRESS AND VARIOUS ALTERNATING STRESSES
STARTING CRACK LENGTH 0.095" NOMINAL

Specimen G-8

Alternating Stress, KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
15	0	0.089	
	10,000®	0.106	
6	0	0.106	
	10,800	0.106	
	12,600	0.108	
	18,000	0.113	
	27,000	0.118*	
	36,000	0.121	1.922
	54,000	0.134	
	72,000	0.144*	
	90,000	0.144	
	108,000	0.150	
	126,000	0.160*	
	144,000	0.184	
	162,000	0.205	2.974
	180,000	0.228	
	198,000	0.262*	
	216,000	0.306	
	234,000	0.365	
	252,000	0.451	
	270,000	0.611	
	276,000	Failed	Average 2.448

Specimen C-11

Alternating Stress, KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
15	0	0.095	
	8,000®	0.114	
8	0	0.114	
	2,700	0.114	
	3,150	0.115	
	3,600	0.117	
	5,400	0.118*	
	7,200	0.122	
	9,000	0.124	
	12,600	0.127	
	16,200	0.131	
	19,800	0.134	3.656
	23,400	0.139	
	27,000	0.144	
	30,600	0.147	
	34,200	0.151	
	36,900	0.155*	
	37,800	0.157	
	41,400	0.165	
	45,000	0.170	
	47,700	0.175	
	54,900	0.190	
	62,100	0.212	
	72,900	0.249	
	83,700	0.298	
	94,500	0.372	
	105,300	0.498	
	114,000	Failed	

Specimen C-5

Alternating Stress, KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
20	0	0.092	
	4,000®	0.111	
8	0	0.111	
	5,400	0.111	
	7,200	0.114	
	10,800	0.119	
	14,400	0.124	
	18,000	0.131	
	21,600	0.133	
	25,200	0.137*	
	28,800	0.144	
	32,400	0.149	
	36,000	0.156	5.254
	43,200	0.169	
	50,400	0.187	
	54,000	0.195*	
	57,600	0.206	
	64,800	0.232	
	72,000	0.261	
	82,800	0.322	
	93,600	0.417	
	104,400	0.600	
	106,000	Failed	

Specimen N-6

Alternating Stress, KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
20	0	0.0995	
	4,000®	0.121	
	0	0.121	
	7,200	0.121	
	9,000	0.124	
	10,800	0.129	
	12,600	0.138*	
	14,400	0.141	
	18,000	0.145	
	21,600	0.156	
	25,200	0.165	6.424
	28,800	0.174	
	32,400	0.184	
	36,000	0.194	
	43,200	0.217*	
	50,400	0.243	
	57,600	0.279	
	72,000	0.386	
	82,800	0.530	
	88,000	Failed	

® Cycles inaccurate because of starts and stops

TABLE XX - Continued

RATE OF CRACK PROGRESSION FOR Ti - 8 Al - 1 Mo - 1 V ALLOY SHEET
TESTED AT 40 KSI MEAN STRESS AND VARIOUS ALTERNATING STRESSES
STARTING CRACK LENGTH 0.095" NOMINAL

Specimen C-8

Alternating Stress, KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
20	0	0.091	
	3,000@	0.102	
10	0	0.102	
	3,600	0.102	
	5,400	0.105*	
	7,200	0.108	
	10,800	0.117	
	14,400	0.124	8.276
	18,000	0.132	
	21,600	0.141	
	25,200	0.152	
	28,800	0.164*	
	32,400	0.178	
	36,000	0.193	
	39,600	0.215	
	43,200	0.241	
	46,800	0.267	
	50,400	0.303	
	54,000	0.344	
	57,600	0.402	
	61,200	0.480	
	64,800	0.570	
	67,000	Failed	

Specimen H-13

Alternating Stress, KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
30	0	0.0995	
	2,000@	0.121	
8	0	0.121	
	21,600	0.121	
	25,200	0.125	
	28,800	0.129	
	32,400	0.141	
	36,000	0.148	
	39,600	0.159*	
	43,200	0.168	
	46,800	0.176	
	50,400	0.186	6.287
	54,000	0.197	
	61,200	0.216	
	64,800	0.229*	
	68,400	0.243	
	75,600	0.279	
	86,400	0.348	
	97,200	0.467	
	107,000	Failed	

Specimen J-7

Alternating Stress, KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
30	0	0.099	
	1,000@	0.117	
8	0	0.117	
	23,400	0.117	
	27,000	0.123	
	28,800	0.127*	
	30,600	0.131	
	34,200	0.137	
	39,600	0.147	5.470
	46,800	0.161	
	54,000	0.178	
	61,200	0.191*	
	68,400	0.215	
	79,200	0.253	
	90,000	0.310	
	100,800	0.397	
	111,600	0.537	
	117,000	Failed	

Specimen P-1

Alternating Stress, KSI	Cycles	Crack Length, In.	$\frac{\Delta \log \ell}{\Delta N} \times 10^6$
30	0	0.095	
	1,000@	0.115	
12	0	0.115	
	5,400	0.115	
	7,200	0.118*	
	9,000	0.126	
	10,800	0.134	
	12,600	0.143	16.05
	14,400	0.153	
	16,200	0.164	
	18,000	0.174	
	19,800	0.188*	
	21,600	0.202	
	23,400	0.218	
	25,200	0.235	
	27,000	0.251	
	28,800	0.277	
	30,600	0.301	
	32,400	0.336	
	34,200	0.369	
	36,000	0.414	
	37,800	0.461	
	39,600	0.526	
	41,400	0.620	
	42,000	Failed	

@ Cycles inaccurate because of starts and stops

TABLE XXI

TITANIUM 8-1-1 ALLOY, CRACK PROPAGATION TEST DATA, SUMMARY

Steady Stress KSI	Alternating Stress KSI	Specimen Number	Crack Propagation K x 10^6	Initial Crack Length Inches	Slope One $Kx10^6$	Slope Two $Kx10^6$	$\frac{K_1-K_2}{K_m}$
0	30	L-5	23.33	0.122	-	-	0.00
0	30	A-8	45.56	0.035	-	-	0.00
0	32	H-7	30.27	0.047	-	-	0.00
0	33	D-5	47.07	0.103	-	-	0.00
0	33	E-6	47.99	0.089	-	-	0.00
0	33	F-13	52.68	0.104	-	-	0.00
0	33	M-4	53.79	0.095	-	-	0.00
0	33	C-9	59.46	0.131	-	-	0.00
0	34	G-4	21.71	0.042	24.46	18.96	0.25
0	34	C-14	26.27	0.044	23.14	29.14	0.24
0	34	D-14	30.81	0.061	-	-	0.00
0	34	I-7	36.62	0.042	-	-	0.00
0	34	D-13	50.93	0.93	-	-	0.00
0	34	N-7	75.80	0.102	-	-	0.00
0	35	J-1	47.23	0.036	-	-	0.00
0	35	D-12	52.45	0.045	-	-	0.00
0	36	L-4	32.02	0.092	-	-	0.00
0	36	A-1	33.07	0.095	-	-	0.00
0	36	M-7	33.09	0.049	-	-	0.00
0	36	E-14	51.56	0.044	48.23	56.89	0.17
0	36	A-2	55.72	0.043	47.82	63.62	0.29
0	36	I-13	67.12	0.100	-	-	0.00
0	38	E-5	30.52	0.048	30.52	8.69	-
0	38	E-10	61.33	0.042	-	-	0.00
0	38	K-4	85.42	0.095	-	-	0.00
0	38	D-11	89.78	0.098	-	-	0.00
0	39	A-10	52.35	0.037	-	-	0.00
0	40	H-9	51.10	0.042	42.02	59.98	0.35
0	40	H-3	51.15	0.046	55.21	47.08	0.35
0	40	A-11	112.29	0.095	-	-	0.00
20	20	I-5	27.60	0.124	-	-	0.00
20	20	A-3	29.53	0.065	-	-	0.00
20	20	L-8	32.97	0.132	35.97	29.97	0.18
20	20	D-10	36.34	0.055	-	-	0.00
20	22	G-5	43.38	0.087	-	-	0.00
20	23	B-7	16.56	0.043	-	-	0.00
20	23	C-6	33.26	0.041	39.56	26.95	0.38
20	24	H-4	28.64	0.094	38.18	19.09	0.67
20	24	B-3	32.70	0.057	-	-	0.00
20	24	M-9	40.15	0.043	40.15	20.12	-
20	24	L-3	41.42	0.110	-	-	0.00
20	24	B-10	42.16	0.075	-	-	0.00
20	24	H-5	42.75	0.114	-	-	0.00
20	24	J-12	42.76	0.106	46.36	39.17	0.17
20	24	G-3	44.07	0.095	-	-	0.00
20	26	G-10	29.97	0.043	29.97	8.53	-
20	26	C-7	48.39	0.031	42.97	53.80	0.21
20	26	L-13	51.52	0.101	-	-	0.00
20	26	H-2	54.82	0.092	-	-	0.00
20	26	C-4	57.50	0.135	-	-	0.00
20	28	L-1	50.35	0.044	-	-	0.00
20	30	F-10	61.65	0.094	-	-	0.00
20	30	F-12B	64.20	0.042	-	-	0.00
20	30	A-5	65.63	0.042	-	-	0.00
20	30	A-14	69.03	0.098	-	-	0.00
20	33	K-11B	66.37	0.043	-	-	0.00
20	33	K-3	70.37	0.096	-	-	0.00
20	33	F-2	78.08	0.108	-	-	0.00
20	33	E-2	104.30	0.045	-	-	0.00

TABLE XXI - Continued

TITANIUM 8-1-1 ALLOY, CRACK PROPAGATION TEST DATA, SUMMARY

Steady Stress KSI	Alternating Stress (KSI)	Specimen Number	Crack Propagation K x 10^6	Initial Crack Length Inches	Slope One Kx10^6	Slope Two Kx10^6	$\frac{K_1-K_2}{K_m}$
40	6	G-8	2.45	0.089	2.97	1.92	0.43
40	8	H-12	3.26	0.055	4.19	2.32	0.58
40	8	C-11	3.66	0.114	-	-	0.00
40	8	D-9	3.72	0.051	-	-	0.00
40	8	E-13	4.10	0.103	-	-	0.00
40	8	K-8	4.24	0.100	-	-	0.00
40	8	C-5	5.25	0.111	-	-	0.00
40	8	J-7	5.47	0.117	-	-	0.00
40	8	B-5	5.58	0.128	-	-	0.00
40	8	D-6	5.69	0.090	-	-	0.00
40	8	B-2	5.83	0.102	-	-	0.00
40	8	F-7	6.18	0.138	-	-	0.00
40	8	H-13	6.29	0.121	-	-	0.00
40	8	N-6	6.42	0.121	-	-	0.00
40	10	N-3	7.27	0.050	8.67	5.86	0.39
40	10	C-8	8.28	0.091	-	-	0.00
40	10	F-7	8.80	0.110	-	-	0.00
40	10	L-11	9.54	0.093	-	-	0.00
40	10	B-1	9.61	0.051	10.60	8.62	0.21
40	10	E-13	9.86	0.125	-	-	0.00
40	10	C-3	11.00	0.104	-	-	0.00
40	10	L-12	12.65	0.093	-	-	0.00
40	10	K-8	14.24	0.180	-	-	0.00
40	10	B-5	14.59	0.165	-	-	0.00
40	11	B-11	12.75	0.041	12.75	4.75	-
40	11	J-2	16.04	0.042	-	-	0.00
40	12	H-11	9.45	0.049	11.26	7.64	0.37
40	12	G-7	10.24	0.041	-	-	0.00
40	12	F-7	11.72	0.098	-	-	0.00
40	12	G-1	11.78	0.061	14.99	8.58	0.54
40	12	K-8	14.24	0.139	-	-	0.00
40	12	J-8	14.32	0.053	-	-	0.00
40	12	G-28	15.62	0.097	-	-	0.00
40	12	P-1	16.05	0.095	-	-	0.00
40	12	K-5B	17.18	0.094	-	-	0.00
40	12	A-6	18.05	0.046	-	-	0.00
40	12	N-2	19.92	0.104	-	-	0.00
40	12	E-13	21.01	0.162	-	-	0.00
40	12	B-5	21.09	0.086	-	-	0.00
40	13	G-9	18.63	0.040	14.32	22.93	0.46
40	13	I-8	19.69	0.040	-	-	0.00
40	14	J-9	22.42	0.042	18.77	26.07	0.33
40	14	E-8	26.13	0.096	21.73	30.53	0.34
40	16	N-9	33.94	0.043	-	-	0.00
40	18	I-1	32.58	0.43	32.58	17.05	-
40	18	M-3	36.45	0.44	-	-	0.00

TABLE XXII

ALTERNATING STRESS CORRESPONDING TO 10^4 DELAY-CYCLES

Crack Length In.	Prior Stress - Ksi		Alternating Stress Corresponding To 10^4 Delay-Cycles - Ksi	
	Mean	Alternating	Mean	Alternating
0.042	0	60	0	42.0
	50	30	0	37.0
	0	45	0	34.5
	0	40	0	32.4
	50	30	20	30.3
	20	55	20	26.7
	20	45	20	21.2
	20	35	20	17.8
	50	30	40	14.0
	40	35	40	12.7
	40	30	40	11.2
	40	20	40	7.2
0.095	0	60	0	39.3
	50	30	0	36.2
	0	45	0	35.3
	0	40	0	29.3
	50	30	20	29.6
	20	50	20	24.6
	20	45	20	20.8
	20	35	20	17.4
	50	30	40	11.7
	40	30	40	10.0
	40	20	40	7.4
	40	15	40	6.1

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